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Earth Systems Associates, Marietta, GA

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FIELD AND LABORATORY EVALUATION OF PETROLEUM LAND TREATMENT SYSTEM CLOSURE

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16. ABSTRACT

The objectives of this research were to measure and interpret the surface soil changes in relation to the quality of runoff water from petroleum refinery land treatment (LT) systems undergoing simulated closure. Waste/soils from four LT sites were studied for chemical transformations in the greenhouse, and one of these sites was also tested under field conditions for runoff quality and waste stabilization. Within the scope of this study, several conclusions were drawn based upon the results: [1] a greenhouse simulation of closure, which has advantages in cost and controlled environment, appears predictive of full-scale results; [2] insignificant downward migration of the organics and metals studied would be expected; [3] grass vegetation (as opposed to no vegetation) will improve runoff water quality by controlling migration of eroded particulates contaminated with organics and inorganics originating from the waste/soil mixture; [4] preliminary screening of soil/waste mixtures and different grasses will be required to identify adverse effects leading to lack of germination and/or grass kill; [5] the zone of soil/waste mixture for LT closure will exhibit essentially no change in total extractable organics and in solubilizable and total metals, and a decline with time in oil and grease and in total chromatographable organics (i.e., boiling point <300°C); [6] for the 10 RCRA Appendix VIII polynuclear aromatic hydrocarbons analyzed, the expected levels in the surface soil/waste mixtures (similar to those investigated) will be ≤ 5 ppm, and these levels may be expected to decrease over 2 years by $\geq 80\%$.

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

The Robert S. Kerr Environmental Research Laboratory is the Agency's center of expertise for investigation of the soil and subsurface environment. Personnel at the Laboratory are responsible for management of research programs to: (a) determine the fate, transport and transformation rates of pollutants in the soil, the unsaturated zone and the saturated zones of the subsurface environment; (b) define the processes to be used in characterizing the soil and subsurface environment as a receptor of pollutants; (c) develop techniques for predicting the effect of pollutants on ground water, soil and indigenous organisms; and (d) define and demonstrate the applicability and limitations of using natural processes, indigenous to the soil and subsurface environment, for the protection of this resource.

This report is a formal research effort aimed at the behavior of organic pollutants and RCRA Appendix VIII constituents under petroleum sludge land treatment closure conditions. The information resulting from this research is valuable in assessing the efficacy of closure practices for hazardous waste land treatment sites.

Clinton W. Hall

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Director
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ABSTRACT

The objectives of this research were to measure and interpret the effect of surface soil changes on the underlying soil and the quality of runoff water from petroleum landfarms undergoing simulated closure. Four landfarm waste/soils were studied for chemical transformations in the greenhouse with one of the same sites tested in the field for runoff quality and waste stabilization. The results obtained at the field site closely paralleled the greenhouse results for the same refinery. The field results over two years showed insignificant downward migration of the organics and heavy metals studied. On the basis of aggregate measures of organics, several compound groups of organics, as well as specific organic species, the closure period of two years in this study allowed significant reductions in waste/soil concentrations. These reductions leveled off or became more slowly changing in the second year of the study. No substantive leaching was observed for inorganic or organic parameters measured in both the greenhouse and the field studies associated with this project. Vegetation improved runoff quality. Some adverse effects on seed germination and vegetation establishment were observed with soil/-waste mixtures in greenhouse studies.

TABLE OF CONTENTS

Page

FOREWORD iii
ABSTRACT iv
FIGURES vi
TABLES vii
ACKNOWLEDGEMENTS viii

1. INTRODUCTION AND PROJECT SCOPE 1
    Project Objectives 1
    Background 1
    Development of Experiments 4
    Summary of Landfarm Closure Literature Review 7

2. CONCLUSIONS AND RECOMMENDATIONS 11

3. EXPERIMENTAL PROCEDURES 13
    Greenhouse Experiment 13
    Germination Experiment 19
    Field Experiment 19
    Chemical Analysis 24
    Data Management 33
    Quality Assurance and Quality Control 34

4. RESULTS AND DISCUSSION 38
    Behavior of Aggregate Organics 38
    Behavior of Fractions of the Total Organic Extract 45
    Behavior of Specific Organics 57
    Gas Chromatographic/Mass Spectrometer (GC/MS) Scan 60
    Behavior of Inorganics 63
    Comparison Behavior of Constituents in Greenhouse Waste/Soil Mixture with Field Waste/Soil Mixtures 71
    Environmental Impacts During Field Closure ... 72

REFERENCES 87
APPENDICES 89

A. Composited Sample Analytical Results 89
B. Non-composite Sample Analytical Results 129
C. GC/MS Plots 153
D. Soil-Water Characteristic Curves 183

FIGURES

Number		Page
3-1	Greenhouse test pot set-up	16
3-2	Field plot layout	21
3-3	Rainfall simulator	23
4-1	Plots of TOC and oil and grease for sites OP/greenhouse and OT/greenhouse and field	40
4-2	Plots of TOC and oil and grease for sites TX/greenhouse and WA/greenhouse	41
4-3	Plots of TCO + GRV for each site	42
4-4 to 4-13	Plots of TCO and GRV measures of organic constituents for greenhouse and field soils (different sites)	47
4-14	Reconstructed gas chromtograms for OT landfarm waste/soil mixture	61
4-15 to 4-19	Plots of total metals for greenhouse and field soils (different metals)	64
4-20	Plots of metals and oil and grease in field runoff	74
4-21	Relation between surface soil and runoff concentrations	76
4-22	Plots of metals concentrations in grass vegetation	80

TABLES

Number Page

1-1 Effects of vegetation on landfarm closure 6

3-1 Site histories of landfarms used in study ... 15

3-2 CEC, pH and texture of landfarm soils used in greenhouse study 17

3-3 Analytical limits and expected coefficient of variation 36

4-1 Rate of mass loss for aggregate organic parameters over two year-closure period 44

4-2 Comparison of chemical concentrations in waste/soil mixtures with control soils 45

4-3 Polynulcear aromatic summary of greenhouse pots and field plots over two year closure simulation period 59

4-4 Changes in gas chromatograph/mass spectra of petroleum landfarm soils 62

4-5 Polynuclear aromatic concentrations from field soils and runoff liquid 78

4-6 Comparison of metals concentrations in grass to those found in long-term municipal land treatment systems 82

4-7 Germination percentages for grass seeds on moist filter paper 83

4-8 Grass height and dry weight after germination in waste/soil mixture and control soils 84

4-9 Germination percentages for grass seeds in waste/soil mixtures and control soils 85

4-10 Fescue germination percentages using surfactant in site WA waste/soil and control soil 86

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CHAPTER 1

INTRODUCTION AND PROJECT SCOPE

PROJECT OBJECTIVES

Land treatment is the treatment and stabilization of wastes applied to a soil-vegetation complex by biological, chemical, and physical processes. In considering the closure of a hazardous waste land treatment system the Environmental Protection Agency has stressed the importance of controlling migration of constituents into ground water and surface water along with release of airborne particulates. The major research objective of this project was to measure and interpret the effect of surface soil changes on the underlying soil and the quality of runoff water from petroleum landfarms undergoing simulated closure. The experimental effort was directed at measuring the changes in the composition of four petroleum landfarm waste/soil mixtures over a two-year closure period in the greenhouse. Simultaneously, one of these waste/soil mixtures was monitored at the original landfarm and runoff liquid samples collected to measure this aspect of land treatment site closure.

Secondary objectives adopted for study included sampling two immediately lower soil zones at the field site to compare field operations with controlled conditions in a greenhouse. In addition, a limited evaluation related to establishing a grass vegetation on a closed land treatment area was conducted.

In the following section of this report a detailed description is provided of the rationale and constraints that led to the selection of these primary and secondary objectives. It is important that the broader context of land treatment site closure and the availability of other research and field information be considered when reviewing the objectives of the project.

BACKGROUND

This research project was established in concept during the period of March-September, 1980 as a joint effort of the U.S. Environmental Protection Agency (R.S. Kerr Environmental Research Laboratory, Ada, Oklahoma) and the American Petroleum Institute (RCRA Waste Management Committee). Over the last several years there has been continued interest and knowledge from other scientific investigations as recognition has grown of the technical and economic advantages of the land treatment alternative to waste management. Within the field of hazardous waste management, land treatment technology and the closure facet of compliance with the Resource Conservation and Recovery Act (RCRA) are very broad in terms of science, engineering, and management requirements.

The aim of this particular research effort was to establish a limited focus on certain aspects of closure which would match the available resources, so that careful documentation and analyses of results could be achieved. A tiered approach was taken in which the bulk of resources was devoted to the primary objective while remaining resources were devoted to selected, complementary sub-studies.

The primary focus of this project was the behavior of petroleum land treatment systems in the closure period. That is, after active use for treating typical petroleum refinery sludges or wastes, use of the land application area is discontinued. During this period, shortly after discontinuing use, practices are employed which in the context of RCRA are referred to as site closure. Closure activities continue until certain environmental standards are achieved at which time a post-closure period begins.

In the context of closure, the U.S. Environmental Protection Agency (1981a) established certain objectives:

1. control the migration of leachate from the zone of active incorporation into ground water;

2. control the release of contaminated runoff to surface water;

3. control the release of airborne particulate contaminates; and

4. comply with the standards established for food-chain crops.

Further, a series of techniques or approaches were suggested for achieving these objectives,

1. "no action" provided the (closure) plan is acceptable from the human health viewpoint and is environmentally sound,

2. the establishment of a permanent vegetative cover, i.e. in-situ conversion to usable land,

3. the capping of the landfarm area with a layer of material which will control infiltration and wind and water erosion, i.e. a landfill-type closure,

4. the removal and landfilling the zone of incorporated waste.

As a part of the decision-making process leading to the specific research project objectives, these four techniques were evaluated in some detail in a literature assessment. This preliminary assessment is contained in a separate report, "Landfarm Closure Literature Review" (Kendall, et al. 1981). The preliminary report on land treatment closure concluded the following:

1. There were four principal approaches to design and management of a closed site.
2. These approaches and the respective total five year costs for a standard site were:
    a. no-action on site but with runoff collection and monitoring ($143,000)
    b. vegetation establishment and runoff collection and monitoring ($193,000)
    c. establish an impermeable clay cap ($707,000)
    d. removal of surface soil to an approved landfill ($1,516,000).
3. A well managed petroleum land treatment area achieving substantial assimilation of waste constituents would not be expected to pose major closure difficulties.

The detailed results of the initial literature-based report are used in the introduction and objectives section of this research project; a detailed summary is provided the reader in a following section of this chapter.

Only certain of the environmental objectives listed above were selected for this research study on closure. The land treatment system interface with airborne impacts was not chosen for experimentation. In relation to the levels of metals and implications for the food-chain, substantial data have previously been collected in a variety of land treatment systems, including those with petroleum refinery wastes. Thus the assimilation of metals was only a second-level objective in this study. With the large-scale installation and utilization of monitoring wells envisioned to occur with RCRA compliance of active petroleum refinery landfarms, the issue of migration of leachate was not selected as a primary objective for study of closure although extensive soil information was collected which relates to leaching.

The remaining environmental objective for the closure period, the release of contaminated runoff, was thus selected as a key focus in this research project. With considerable prior information in the fields of pesticide, fertilizer, and animal waste runoff it has been established that surface soil conditions and the corresponding runoff liquid are the major facets of this environmental pathway.

DEVELOPMENT OF EXPERIMENTS

This project was constructed to determine the changes in the composition of the surface waste/soil complex over an extended period of time during closure and to measure actual runoff liquid concentrations of waste/soil constituents. Research in the rainfall-runoff field (so-called non-point sources of pollution) has typically been either,

1. edge-of-field studies focusing on the relation between the surface soil conditions and the immediate liquid from the field, or

2. receiving stream evaluations which integrate the effects of various land uses (including land treatment areas) and the dynamics of surface water hydrology.

Since hazardous waste land treatment sites are uniquely required to collect and/or assess the rainfall runoff in the immediate vicinity of the application area, the edge-of-field approach was selected for this research.

As a result of the preliminary review of literature regarding closure, two techniques (no action and in-situ conversion) were judged as the most cost-effective means of compliance with various environmental objectives for closure (see previous list of alternatives). These two means of achieving closure (referred subsequently as non-vegetated and vegetated) were used to focus this closure-related research.

In summary, the primary objectives of this research center on the behavior of waste constituents in the surface soils of petroleum landfarms when undergoing closure using either vegetation or no vegetation approaches to closure, and the corresponding runoff liquid measurements of inorganic and organic constituents.

Secondary objectives were also established in this project recognizing the opportunity to collect additional information from the experimental set-up. Sampling of the lower soil layers below the more influential runoff-controlling surface soil was conducted to partially assess leaching of waste constituents. Since the difference in the more cost-effective approaches for closure compliance centers on vegetation, a sub-study was undertaken to evaluate germination on petroleum waste/soil mixtures as a necessary step in vegetation management. A third sub-study on capping was initially undertaken, but was abandoned since the resources available did not permit a viable experimental arrangement.

In the context described above, the specific research plan was developed jointly by the API RCRA Waste Management Task Force (M.A. Buerchlin, W.J. Clark, V.F. Coty, G.W. Grove, R.L. Huddleston, J.M. Johnson, A.B. Puch and J.E. Rucker), the EPA (F.M. Pfeffer, Project Officer), and the project technical investigators (W.L. Nutter, R.L. Kendall, and M.R. Overcash). The components of the specific study are described herein as an overview.

A single field site and three other sites for the greenhouse study were selected. In general, petroleum land treatment areas are operated with rates of application

1. established to optimize oil waste treatment, or

2. to largely obviate extended closure periods.

Since the majority of petroleum land treatment systems use the former operating mode a single field site was selected to reflect these practices. The field site would provide over an extended period of time the opportunity to measure changes in the surface conditions. A rainfall simulator was chosen to produce runoff liquid from nearly identical events spaced over approximately six month periods for 2.5 years. Resources precluded the use of a second landfarm as a field site; however, at the location chosen multiple test plots were established within vegetated and non-vegetated waste amended areas and non-vegetated control areas.

Samples for the major portion of the investigation were composited within similar soil surface conditions, thus providing some measure of average conditions, but without the benefit of statistical replication.

An effort was made to broaden the landfarm conditions studied by adoption of a parallel greenhouse investigation. Four petroleum landfarms with areas available for closure were selected to collect surface soils for experimentation. One of these was the field location so that some comparative relation could be developed between greenhouse and field information. Such multiple site experiments in a greenhouse were much less costly than equivalent field studies and have the advantage of providing a controlled environment. In the greenhouse the variables of vegetated waste/soil, non-vegetated waste/soil, and non-vegetated control soil were used in an analogous fashion to the field. However, only the soil changes over time were investigated in the greenhouse, with runoff liquid studies confined to the larger field study.

The advantages of vegetation in the management of a petroleum waste land treatment location undergoing closure involve a number of factors. These are listed in Table 1-1. For this research, only the effect of vegetation on soil stabilization to reduce surface runoff was subject to experimental investigation.

TABLE 1-1. EFFECTS OF VEGETATION ON LANDFARM CLOSURE

Vegetation Effect	Function
Protective	Soil stabilization against water erosion Soil stabilization against wind erosion Increased infiltration Decreased runoff
Cycling	Increased evapotranspiration Decreased soil water content Translocation and transformation of excess nutrients
Other	Indicator of hot spots where excess chemicals have accumulated Aesthetically pleasing appearance

From the general experimental system described above, samples were taken at approximately six-month intervals over a period of 2 to 2.5 years from the implementation of closure status corresponding to the summer of 1982. These samples consisted primarily of surface waste/soil material or runoff liquid with some vegetation samples also taken. For the primary samples, the chemical constituents which were selected for analyses were chosen to reflect both the agronomic and environmental requirements of the closure approaches investigated. These parameters were in three groups:

1. macro- and supplementary nutrients and conditions important to vegetation growth;
2. metals - the most prevalent criteria for judging the long term closure status;
3. organic parameters reflecting aggregate measures of organics and oil, specific groups representing fractions of petroleum-related wastes, and specific compounds (many of which are a part of the suggested closure monitoring list (Federal Register, 1980).

It should be noted that the decision was made, based on available resources, not to undertake analytical replication but rather to composite samples from experimental replicates.

For the soil studies, the same field and greenhouse soils were used. Samples of the soil directly below the zone of incorporation were taken in the field and greenhouse and soil samples from a third lower depth were taken from the field. These additional mid- and lower-depth samples were analyzed for a subset of the parameters characterizing the upper soil. This subset of parameters were thus a measure of migration under field and greenhouse conditions. In addition, a germination sub-study was instituted to assess the feasibility of establishing vegetation during the land treatment closure period.

This report covering the experiments and objectives described above has been structured to be concise and to utilize appendices for data and other supplementary material. The conclusions and recommendations are presented in Chapter 2 and the following chapter provides a detailed description of materials and protocols used throughout this project. These include the field system, greenhouse studies, sampling and chemical analyses, and data management. Finally, the results are given with respective detailed discussions of information.

SUMMARY OF LANDFARM CLOSURE LITERATURE REVIEW

A report entitled "Landfarm Closure Literature Review" was prepared by R.L. Kendall, H.P. Arora, and J.R. Wallace of Law Engineering Testing Company and submitted to the American Petroleum Institute and the U.S. Environmental Protection Agency in December 1981. The report identified the potential methods of closure and presented cost estimates for each. The results of the report were used to redefine the objectives of the remainder of the project. The summary and conclusions of that report are presented in the following paragraphs.

The decommissioning of a landfarming facility requires a closure plan which is technically feasible, meets regulatory constraints for environmental acceptability, and is cost-effective. Although specific criteria for testing and compliance with regulatory constraints have not been established. U.S. Environmental Protection Agency guidelines call for the owner/operator to develop a performance based closure plan which addresses the following objectives:

1. Control the migration of leachate from the zone of active incorporation into ground water.
2. Control the release of contaminated runoff to surface water.
3. Control the release of airborne particulate contaminants.
4. Comply with the standards established for food-chain crops.

Law Engineering reviewed the operational considerations, environmental effects, monitoring criteria, and the cost of construction and maintenance of U.S. Environmental Protection Agency suggested methods for landfarm closure. The closure methods reviewed fall into four categories, i.e., land management alternatives, which include,

- the so-called "no action" plan, and
- the in-situ conversion to usable land
- landfill-type closure (capping), and
- removal of contaminated soil.

From an available review of existing petroleum land treatment systems (U.S. EPA, 1981b), a median size system was chosen as an example to facilitate a comparison of alternative closure methods. This site was two hectares in size, in the Gulf Coast states, and within 24 km of native clay materials. Closure was assumed to occur over 5 years, with an eight percent inflation, and with a 20 percent discount rate for present net worth (1980 to 1981).

The "no action" closure is ideally suited where the site conditions are such that the potential for off-site migration is low. Where such conditions are present, this option is a practical and cost effective alternative and is easy to implement. In the "no action" plan it may be necessary to continue cultivation practices until the waste is degraded to a stabilized condition after which an unrestricted use of the site may be possible. Volunteer vegetation is allowed to grow without the benefit of seeding and care. The net present cost of "no action" closure for an approximately two ha (five acre) site was estimated to be $143,000 over a period of five years. Maintenance of a surface runoff collection system and monitoring of surface runoff, the cost of which is included in the above estimate, may be required until the runoff quality is shown to be environmentally acceptable.

Major emphasis in the in-situ conversion alternative is the establishment of a permanent vegetative cover which stabilizes the waste disposal area, reduces surface runoff, absorbs chemical constituents of the waste, and helps improve the aesthetic appearance. Perennial grasses generally provide the maximum degree of site protection. Regular fertilizer and lime additions are necessary for the establishment and maintenance of vegetation. Plowing may be necessary to fully mix the waste, aid its degradation, and prepare the seed bed for vegetation establishment. It is estimated that the net present cost of establishing a vegetative cover and maintaining and monitoring an approximately two-hectare site would be approximately $193,000 over a five-year period. A monitoring program to assess the migration of potentially hazardous waste constituents into ground water and to determine the potential release of these constituents via surface runoff would be required.

Law Engineering's review of pertinent literature suggested that the placement of a capping material (the third closure alternative approach) may potentially convert nondegraded or partially degraded landfarmed materials to a mobile phase. If the decision is made to cap a landfarm, certain evaluations of the system should be conducted. A recent U.S. Environmental Protection Agency document outlines the sequence of procedures for an evaluation of the characteristics of the cover system, assessment of its adequacy and a maintenance plan (Federal Register, 1980). Such procedures were considered in the current study. It is estimated that the net present cost of the installation and maintenance of an impermeable soil cover along with monitoring costs would be approximately $707,000 at a two-ha site for a period of five years.

Contaminated soil removal is expected to be the most expensive closure option when one considers the very large volume of soil that may have to be removed, transported, and disposed of at a secure landfill facility. Site excavation and off-site disposal may perhaps be a desirable and cost effective option if extensive soil contamination is confined to a small area. Excavation of the soil/waste mixture and its transport and disposal to a secure landfill facility located at a distance of 15 miles would cost approximately $1,516,000 for a two ha site.

A review of the current literature indicates that a variety of refinery waste streams of diverse chemical make-up have been successfully landfarmed for more than 25 years in an environmentally acceptable manner. A number of field and laboratory studies have indicated that there is minimal potential for off-site contamination and that groundwater quality is not endangered at judiciously located and well managed landfarms. Therefore, landfarm closures are not expected to present a significant environmental problem. Although the ultimate choice of a closure method would depend on geohydrologic conditions of the site and chemical make-up of the applied waste, closure alternatives based on land management procedures appear to provide low cost and environmentally acceptable options.

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

The following summary statements apply to the results of this two year simulation of petroleum landfarm closure in the greenhouse and on field plots.

1. Field results at a closed refinery land treatment (LT) system closely paralleled the results obtained in a greenhouse simulation of closure using soil/waste obtained from the same refinery. This being only one comparative study, no firm conclusion can be drawn as to whether the greenhouse studies using soil/waste mixtures from three additional refineries would adequately predict full-scale results at the respective locations. However, it can be concluded that greenhouse simulation studies, which have advantages in terms of cost and controlled environment may be an important aspect of full-scale closure evaluation at a LT system; and at such time that results are statistically comparable, emphasis might be shifted to the greenhouse studies at a considerable cost savings. It can also be concluded that the results of this study for one refinery operation suggest that future comparative greenhouse/field studies will show the predictive usefulness of the greenhouse, leading hopefully to the emphasis being placed on greenhouse simulation with periodic field confirmation.

2. Based on two years of data collected at one land treatment closure site, closures having similar conditions of waste soil and climate will have insignificant downward migration of the organics and heavy metals studied.

3. Based on field results at one refinery for 2 years, grass vegetation (as opposed to no vegetation) will improve runoff water quality by controlling migration of eroded particulate material contaminated with organic and inorganic constituents originating from the waste/soil mixture.

4. Based on greenhouse results representing four refinery land treatment systems and three native grasses, preliminary testing of soil/waste mixtures and different grasses is recommended to identify adverse effects that may result from incomplete germination and/or grass kill.

5. Based on controlled greenhouse studies of 2-years duration, the zone of soil/waste mixture for land treatment closure will exhibit essentially no change in total extractable organics and in solubilizable and total metals; the mixture will also exhibit an asymptotic decline with time to above background levels in oil and grease and in total chromatographable organics (i.e., boiling point $\leq 300^\circ$ C).

6. For the ten RCRA Appendix VIII polynuclear aromatic hydrocarbons (PNA's) analyzed in field and greenhouse studies, the expected levels in the surface soil/waste mixtures (similar to those investigated) will be $\leq$ 5 ppm. These levels may be expected to decrease over 2 years by $\geq$ 80%.

CHAPTER 3

EXPERIMENTAL PROCEDURES

GREENHOUSE EXPERIMENT

A commercially-available greenhouse was constructed to house the laboratory experiment. The structure, which measured 4.3 m by 4.3 m, consisted of an aluminum frame over which clear polyethylene was stretched and clamped in place. The greenhouse was equipped with a thermostatically controlled exhaust fan set to operate whenever the temperature inside exceeded 27° C. To restrict insolation and thereby reduce the heat load during the summer (May to September) a coating of whitewash was painted over the outside surface of the greenhouse.

In order to maintain a minimum temperature during the cool season a thermostatically controlled natural gas space heater was installed. The heater was set to operate whenever the temperature fell below 4° C. The whitewash coating was removed from the outside surface during October to increase insulation during the winter. A maximum-minimum thermometer was placed in the greenhouse to document the performance of the heater and exhaust fan.

Soils for the greenhouse experiment were obtained from four landfarms representing different geographic/climatic areas of the country. The landfarm locations were in the states of Washington (WA), Texas (TX) and Oklahoma (OP and OT). The Washington site is located in the humid zone between the Pacific coast and the Cascade Range. The Texas site is located along the Gulf of Mexico in a humid climatic zone. Two sites are located in eastern Oklahoma in a semi-humid climatic zone. One of the sites in Oklahoma (OT) also provided the location for the field testing.

A soil sampling protocol was provided to each participating refinery, giving instructions on how to select sampling locations and how to collect and prepare samples for shipment. Each refinery was requested to provide both treated and adjacent untreated (control) soils. The treated soils were to have received refinery oily wastes while the control soils were to be from the same soil type with no wastes added. Samples were taken at five locations within the treated area and five locations in the control area from the upper 10 inches of soil. The subsamples were mixed thoroughly and placed in plastic-lined metal drums for shipment. Information on amount and type of wastes applied, date of last application and typical site management operations was requested from each refinery. A summary of the site information is presented in Table 3-1.

Examination of Table 3-1 indicates a variety of practices and to a certain extent the type of waste that had been land treated. The oil application rate ranged from approximately 90 to 2,800 kg oil/ha/yr. Over the respective lifetimes of the sites used for waste treatment, the accumulated amount of oil was 135 to 2,700 kg/ha. All of the landfarms practiced discing or rototilling to enhance aerobic soil conditions, but not all used fertilizers to accelerate oil degradation. Finally the time period prior to soil collection for these experiments since waste had last been applied to each site varied from 0.25 to 4.5 years.

The experimental setup for the greenhouse experiment is shown in Figure 3-1. Glazed ceramic pots approximately 29 cm in diameter were used to hold the experimental soils. A ceramic 1-bar pressure plate cell was placed in the bottom of each pot to maintain a relatively constant moisture content in the subsoil. Tygon tubing one-meter long with a 0.25-cm inside diameter was attached to the outlet port of the plate and passed through a small hole drilled through the side of the pot. The pressure plates were saturated with water and de-aired prior to placement in the pots. Ceramic spacers were placed underneath the pressure plates to allow the neoprene diaphragm under the plate to expand or contract with changing soil moisture conditions. The tubing extending from the outlet port was filled with water and clamped at the end.

Soils from each landfarm were analyzed for cation exchange capacity (CEC), pH, texture and moisture-pressure relationships before being placed in the ceramic pots. Moisture characteristic curves are presented in Appendix D. Soil texture data, CEC and pH are presented in Table 3-2.

As evidenced by Table 3-2 all of the soils had a sandy to loamy texture which typically imparts good drainage characteristics to a soil. The treated soil at each landfarm exhibited a coarser texture than the control soil because of the presence of water stable aggregates. Cation exchange capacity and pH varied considerably between sites and between treated and control soil at each site.

To provide a substrate for the landfarm soils a local Georgia subsoil with a loamy texture was obtained from a nearby construction site. All soils were passed through a five-mm screen mesh to remove any large particles before the soil was placed in the pots. Subsoil was placed in each pot to a depth of 15 cm at a density of 1.2 g/cc.

TABLE 3.1 SITE HISTORIES OF LANDFARMS USED IN STUDY.

	Site Description			
	OT	WA	OP	TX
Date Begun	July 1976	June 1972	1978	1973
Type of Waste	API separator and air flotation sludges	API separator sludge, equalization sludge, oily tank, waste, composted biosludge	18 different refinery waste-streams	API separator and MEA sludge, oils w/PNA's, crude tank bottoms, slop treating sludge, tank/still bottoms, oily silt/sand and contaminated dirt, unleaded tank sludge
Average or estimated rate of sludge application, mt/ha/yr	16,800	1,300	3,700	27,000 mt
Oil application rate, mt/ha/yr	3,700	180	70	---
Oil in sludge, % wt. oil	22	14	5-10	---
Time between sampling and last application, years	4.5	1.0	0.25	0.25
Landfarm operations	rototill to 20 cm, 1,500 kg N/ha/yr, 1,200 kg P_2O_5/ha/yr	discing once/yr, no fertilization	rototill when dry in summer, infrequent fertilization	Cultivated regularly, no fertilization
Total oil application, mt/ha	5,400	1,600	270	---

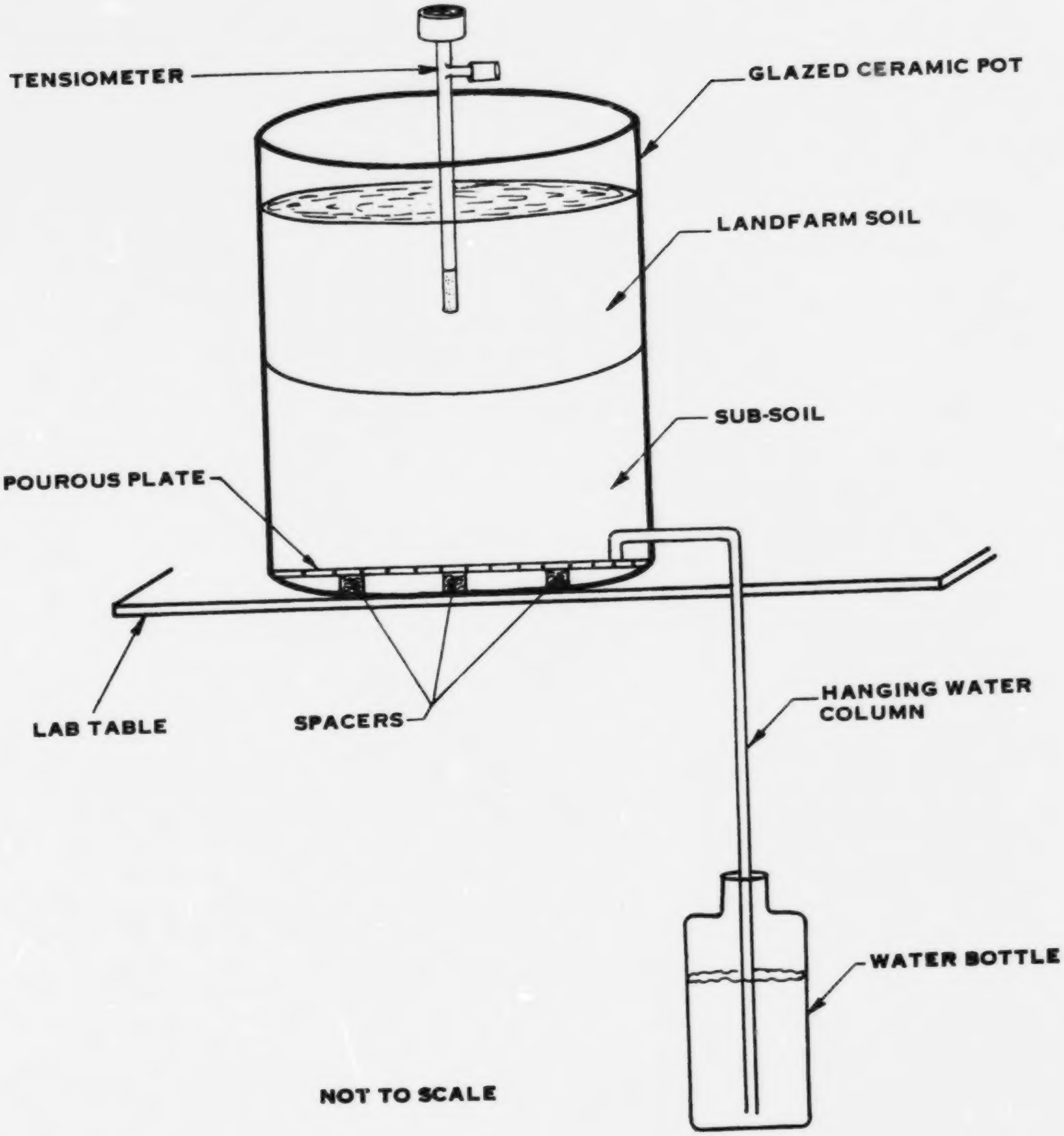

TENSIOMETER
GLAZED CERAMIC POT
LANDFARM SOIL
SUB-SOIL
POUROUS PLATE
LAB TABLE
SPACERS
HANGING WATER COLUMN
WATER BOTTLE
NOT TO SCALE

FIGURE 3-1. GREENHOUSE TEST POT SET-UP CUT-AWAY VIEW

TABLE 3-2. CATION EXCHANGE CAPACITY pH AND TEXTURE OF LANDFARM SOILS USED IN GREENHOUSE STUDY

Soil	CEC	pH	Texture
	meq/100g		
OP Control	11.5	6.5	Silt Loam
OP Treated	9.8	5.8	Sandy Loam
OT Control	9.7	7.0	Sandy Loam
OT Treated	9.4	6.8	Loamy Sand
TX Control	23.6	7.7	Sandy Loam
TX Treated	49.4	5.5	Loamy Sand
WA Control	10.6	4.8	Loam
WA Treated	3.8	4.9	Loamy Sand

Landfarm soils were placed over the subsoil at the same depth and density as the subsoil. Each landfarm treated soil was used to fill seven pots and each control soil was used to fill three pots. Three of the treated soil pots from each landfarm were planted with fescue grass to provide the vegetated experimental condition. Fertilizer equivalent to 1125 kg/ha (1,000 lb/ac) of a 5-10-10 N-P-K blended fertilizer was added to each vegetated pot to improve vegetation growth. Three treated pots and two control pots were left unvegetated to provide the non-vegetated condition. One treated and one control pot were kept unvegetated as extras.

After soil placement was completed the forty pots were set up on lab benches in the greenhouse. The water filled tubes connected to the saturated porous plates were placed in bottles of water approximately one meter below the benches. A separate bottle was provided for each pot. By maintaining a constant level in the water bottles the moisture tension in the subsoil of the pots could be maintained relatively constant. To monitor tension in the test soils overlying the subsoil, one pot for each experimental condition and each landfarm was equipped with a vacuum gage tensiometer installed at a depth of 10 cm. Readings taken routinely from the tensiometers were used to schedule water applications to the pots.

The objective in applying water to the pots was to minimize leaching while at the same time maintain moisture tension in the test soil in the range of 0.3 to 0.8 bar. When tension exceeded 0.8 bar on a tensiometer water was added to that set of pots to bring the tension down to 0.3 bar. Close monitoring during the initial stages of the experiment yielded a water volume for each set of pots that would achieve the desired response without causing immediate measurable leaching. Because of differing particle sizes and adhesion properties of the soils the water volume required to achieve the desired effect in each set of pots was different.

Soil samples for chemical analyses were taken in June 1982 before the experimental pots were set up and at four later dates; November 1982, June 1983, November 1983 and June 1984. After the pots were set up, sampling was accomplished using two thin wall stainless steel tubes. A tube with a diameter of 3 cm was used to sample the experimental soil in the upper 15 cm of each pot. The subsoil was sampled by inserting a 2.5 cm diameter tube in the hole created by the 3 cm tube. Samples were pushed from the tubes by a wooden dowel. After sampling was completed the holes were filled with subsoil and experimental soil from the extra pot reserved for each treatment. Sampling locations were marked so that no subsequent sampling would take place at the same location.

Samples from the replicate pots (three replicates for the treated soils and two for the control soils) were combined and thoroughly mixed. Subsamples were taken from the soil mixtures for delivery to the four laboratories participating in the study. Samples for organic analyses were placed in paper bags and then sealed in air tight plastic bags to reduce volatilization. The remaining samples were crushed, air-dried and sieved through a No. 10 sieve (2 mm opening) before being delivered to the respective laboratories.

During the summer of 1983, heat stress caused nearly complete mortality of the fescue grass planted during the previous fall. To re-establish vegetative cover the pots were planted in July 1983 with sprigs of Coastal bermuda grass which is a warm season perennial. Fertilizer equal to that applied with the fescue grass was mixed with the soil at the time of sprigging. Establishment was effective in all but the WA treated soil which appeared to be too hydrophobic to retain adequate moisture for growth of the grass. Vegetation was sampled during November 1983 and June 1984 by clipping the above-ground live stems and leaves. Grass samples were air dried before shipment to the laboratory.

GERMINATION EXPERIMENT

Three grass types were chosen, based on information developed by the U.S. Environmental Protection Agency (U.S. EPA, 1980). The basis for selection was to include grasses which based on climatic preference would be common to the four petroleum landfarm systems in this project. Based on this criterion the following grass species were selected:

1. fescue (Festuca arundianacea schreb),
2. orchardgrass (Dactylis glomerata),
3. redtop (Agrostis alba).

The grass seed was purchased commercially in the Atlanta area.

Waste/soil and control soil from two sites, OT and WA, were chosen for a total of four growth media. Each experiment was done in triplicate. Small aluminum trays (15 cm x 7.5 cm x 7.5 cm deep) were used to contain the soils. A small number of holes were cut in each container to allow the soil to drain. Trays were put in an area receiving daylight during the periods of September 1983 and March 1984. The trays were moistened frequently to maintain good germination and growth conditions.

A known number of grass seeds were placed in each of the four growth media. In the first experimental period, the height of all grasses was measured after 15 and 64 days. At 64 days the grass was harvested and green weight and moisture content determined. During the second experimental period, more frequent measurements of height and percent germination were made, followed by harvesting and weighing at 64 days.

As a control for the vegetation experiments a seed viability or germination control test was performed. A known number of seeds was placed on moist filter paper in a covered Petri dish. Within a few days, the percent germination was determined. In comparison to soils or waste/soil mixtures this seed viability represents the maximum potential for each seed type to germinate.

FIELD EXPERIMENT

The field experiment portion of this study was conducted at the OT refinery site that provided soil for the greenhouse experiment. Test plots were established in an experimental field that had been the subject of several previous studies. The study area was the same area that had been sampled for the greenhouse experiment.

The sampling program for the field study included collecting soil samples and runoff samples from vegetated waste soils, non-vegetated waste soils and non-vegetated control soils. In order to collect runoff samples a series of %infiltrometers were constructed and installed in the field. A total of nine infiltrometer plots were set up according to the layout shown in Figure 3-2.

Infiltrometers were constructed of pressure treated 2.5-cm x 15 cm boards to form a one-m x one-m frame. A V-notch was cut in the low elevation side to provide a collection point for runoff. Narrow trenches approximately five-cm wide and 20-cm deep with one-m x one-m dimensions were excavated in the test strips for installation of the infiltrometer frames. After the frames were set in place the soil was backfilled inside and outside of the frame and tamped in place. The soil surface inside the frame was shaped to form a minimal slope toward the V-notch. An aluminum spout was nailed to the V-notch and sealed with silicon caulk. A hole was excavated outside the plot at the end of the spout to allow runoff samples to be collected in wide mouth one-liter bottles.

Infiltrometer construction took place in June 1982 with the first sampling scheduled for November 1982. Sprigs of common bermuda grass were planted in the three vegetated plots after the infiltrometer frames were installed. Insufficient rainfall resulted in complete mortality of the sprigs during the summer of 1982. To provide a vegetative cover before the first sampling event, fescue grass was seeded in late September 1982. Fertilizer was applied at a rate equivalent to that added to the greenhouse pots. The vegetated plots were irrigated approximately once each week up to the time of the November sampling event. Grass covered about 75 percent of each plot at an average height of about two cm when the November sampling was conducted.

By June 1983 volunteer common bermuda grass had invaded both vegetated and non-vegetated plots. Coverage was approximately 25 percent. Sprigs were removed from the non-vegetated plots by clipping prior to collection of runoff samples. After runoff had been collected the root structure of the volunteer grass was removed as much as possible from the non-vegetated plots. By November 1983 the vegetated plots had nearly 100 percent coverage while the non-vegetated plots had about 10 percent coverage by re-invasion of volunteer grass. Removal of grass from the non-vegetated plots was required before each subsequent sampling event.

Rather than relying upon natural rainfall events to generate runoff from the infiltrometer plots a device was constructed to simulate rainfall. The device, called a rotating disk rainfall simulator, was constructed using a design developed by Morin, et al. (1967) and modified by Donnelly (1981). Figure 3-3

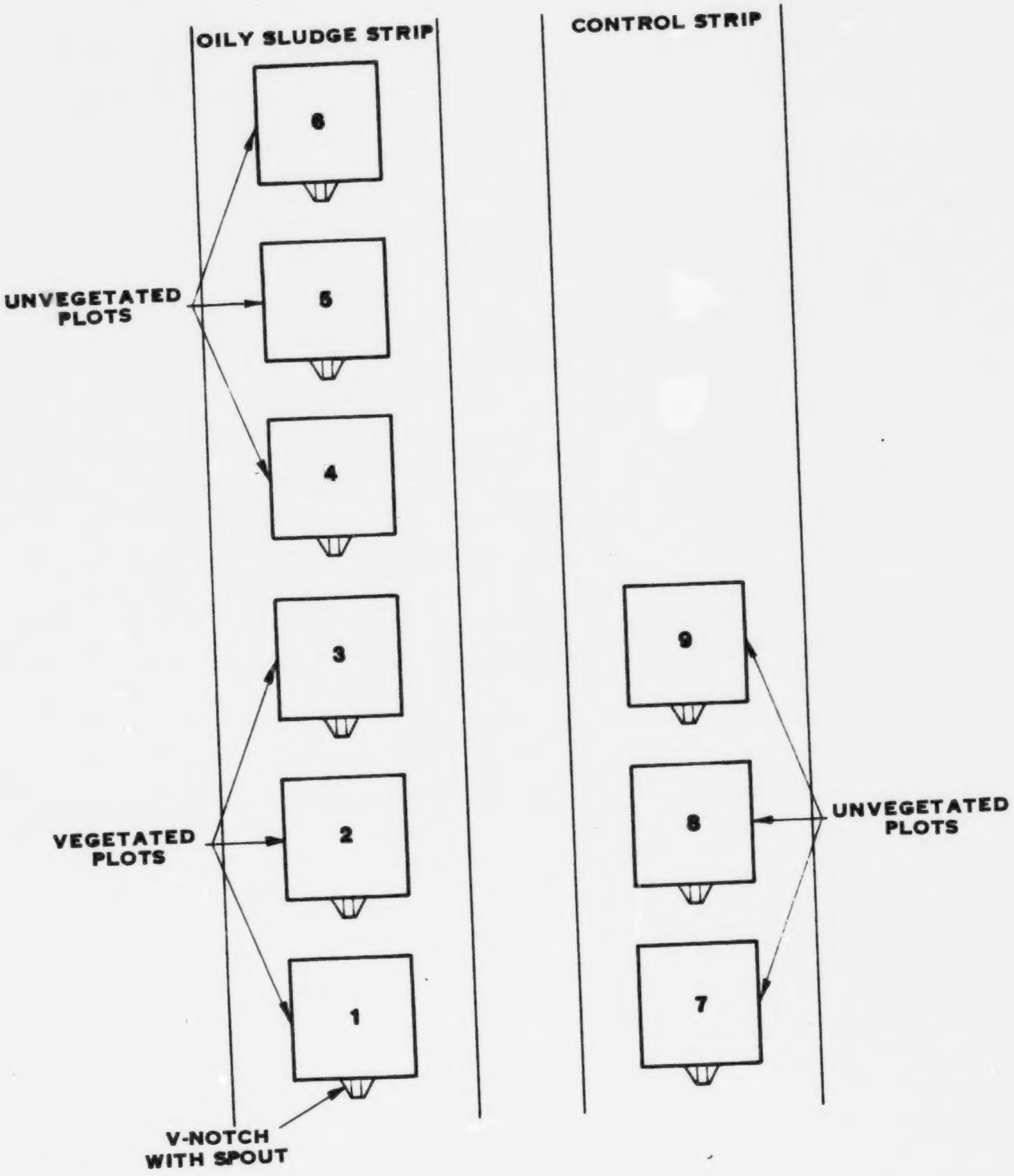

OILY SLUDGE STRIP
CONTROL STRIP
6
5
4
3
2
1
9
8
7
UNVEGETATED PLOTS
VEGETATED PLOTS
UNVEGETATED PLOTS
V-NOTCH WITH SPOUT

FIGURE 3-2. FIELD PLOT LAYOUT

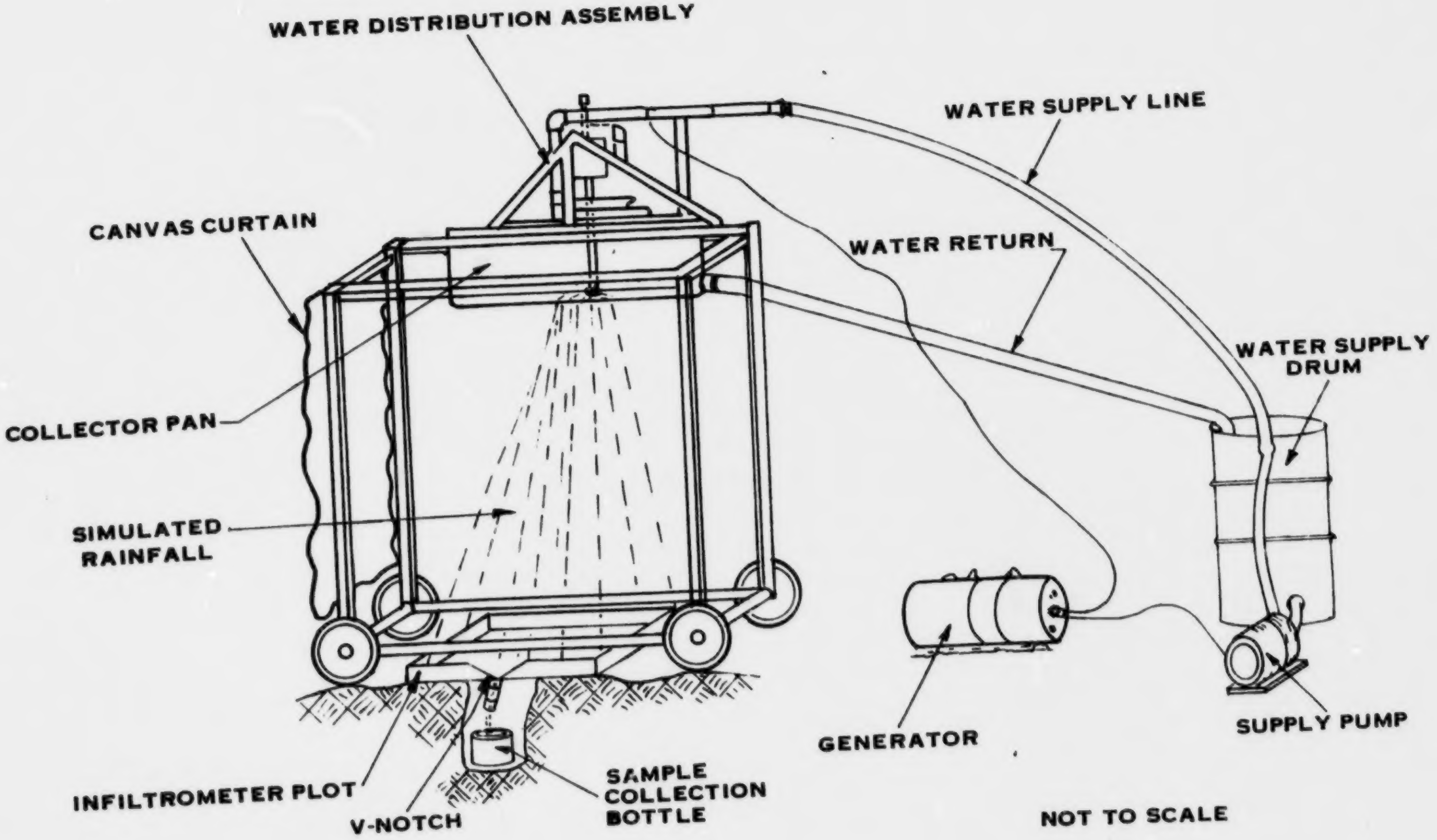
illustrates the components of the rainfall simulator used for the experiment. The water distribution assembly was attached to a steel frame and mounted on flotation tires to allow movement of the unit in the field. The pump, generator and water supply drum were placed on a utility trailer to allow the entire simulator to be easily moved between plots.

The rotating disk rainfall simulator uses a high capacity, large orifice nozzle to approximate the droplet size and impact velocity of natural rainfall. To control the application rate a rotating disk with an adjustable aperture is placed below the nozzle to physically remove a portion of the water stream from the high capacity nozzle. The water deflected by the rotating disk is collected in a pan and returned to the supply drum where it can be recirculated to the water distribution assembly. Approximately 95 percent of the water pumped to the nozzle is returned to the supply drum.

The aperture in the rotating disk can be adjusted to simulate a rainfall intensity ranging from 17 mm/hr to 152 mm/hr with uniform coverage. An intensity of 51 mm/hr (2 in/hr) was selected for the field experiment to represent a high intensity rainfall event during which runoff and accompanying soil transport would be measurable. A series of test runs were conducted to set the water supply rate and aperture size that would achieve uniformity at the desired application rate. Following these tests the aperture and supply valve were fixed and left constant throughout the study.

The first sampling was conducted in November 1982 with subsequent sample events conducted in June 1983, November 1983, June 1984 and November 1984. Both soil and runoff samples were collected during each event. Soil samples were collected adjacent to and outside of the infiltrometer plots using a standard 10-cm diameter soil auger. Three depths were sampled in each hole: 0 to 25 cm, 25 to 50 cm and 50 to 75 cm. The upper sample represented the zone of waste incorporation while the two lower samples were below the zone of incorporation. Samples for each depth were composited according to treatment to yield a total of nine composite samples for analysis. After collection, samples were handled similarly to the greenhouse soils.

Runoff was generated by setting up the rainfall simulator over each plot and operating it until sufficient sample had been collected. Approximately two liters were collected from each plot for the analyses scheduled for the runoff samples. The time required to generate runoff varied between plots and between sample events, depending on soil properties, vegetative cover and antecedent soil moisture content. In general the control plots produced runoff within five to 15 minutes of the start of operation. Full sample volume was typically collected within 10 to 20 minutes of start up of operation for the control plots.



WATER DISTRIBUTION ASSEMBLY
WATER SUPPLY LINE
CANVAS CURTAIN
WATER RETURN
WATER SUPPLY DRUM
COLLECTOR PAN
SIMULATED RAINFALL
GENERATOR
SUPPLY PUMP
INFILTROMETER PLOT
V-NOTCH
SAMPLE COLLECTION BOTTLE
NOT TO SCALE

FIGURE 3-3. RAINFALL SIMULATOR

On the waste amended plots a greater length of time was typically required to generate runoff and to collect the full sample volume. Little time difference existed between vegetated and non-vegetated plots within the waste amended soils. Runoff was first produced at 25 to 50 minutes and full sample volume was collected after 40 to 80 minutes.

Following collection of runoff from each plot the rainfall simulator was moved to the next plot and set up for operation. While the simulator was running the runoff sample from the previous plot was separated with half the sample poured into an acid-rinsed 3.8 liter glass bottle and placed on ice in a cooler. The remaining half of the sample was filtered through a 45-um membrane filter using a small portable vacuum filtration unit. The filtered sample was transferred to a second 3.8 liter glass bottle and placed in the cooler.

Samples from the three plots for each experimental condition were treated in a similar manner and combined in the 3.8 liter glass bottles to yield one filtered and one unfiltered sample for each of the three treatments. After the filtered and unfiltered composite samples for each experimental condition were collected the samples were transferred to individual sample containers and preservatives appropriate for the particular tests were added. After all samples were collected the samples were shipped in coolers on ice to the participating laboratories.

Sampling of vegetation for analysis of metals uptake was scheduled for the three November sampling events. Because of poor growth of vegetation on the plots for the November 1982 event, samples were not collected at this time. Samples of the volunteer bermuda grass were collected in November 1983 and November 1984 from the vegetated plots. Grass samples were air dried before being delivered to the laboratory.

CHEMICAL ANALYSIS

Organics

Total Chromatographable Organics (TCO)--

Sample preparation -- The soil was air dried overnight.

Digestion or extraction -- A weighed sample of about 100 g was transferred to a Soxhlet thimble. An extraction with 400 ml of methylene chloride was conducted for 24 hours in a Soxhlet apparatus. Methylene chloride is a solvent which gives high extraction efficiency for a wide range of organic compounds. In particular, it is generally effective for non-polar and moderately polar hydrophobic organics which are the types of compounds that dominate many current lists of "chemicals of concern."

After the extraction, the final volume of methylene chloride was measured for use in the final concentration calculations. Drying of the methylene chloride extract was accomplished through a Na_2SO_4 column. A 10 ml aliquot was taken and refrigerated for future reference. At this point some knowledge of the sample organics level was used to assess the need for further concentration. If, based on coloration, the sample appeared to have high contents of chromatographable organics, a one-ul aliquot was taken for analysis. Otherwise the methylene chloride sample is placed in a Kuderna-Danish evaporative and the volume reduced to about 10 ml to 25 ml (resulting in an approximately 40-fold concentration increase). From this level, a one-ul aliquot is taken for analysis directly (if greater than about 30 ug TCO/ml); or if found to be beyond the range of the calibration curve, a dilution is made appropriately to keep below about 400 ug TCO/ml in the injected aliquot.

Analytical technique -- The Total Chromatographable Organics (TCO) analysis is a gas chromatographic (GC) analysis procedure that uses a flame ionization detector. A one- to five-ul aliquot of the sample can be injected. Resolution of individual GC peaks is not intended. The total integrated detector response is used to derive a single estimate (mg) of the quantity of material in the 100 to 300° C boiling point range. The lower detection limit (LDL) for a complex sample mixture is on the order of 50 ppm (w/v) in the solution injected. This corresponds to 0.5 mg total in the 10 ml sample extract. Based on an initial sample of 100 g of soil and 400 ml of methylene chloride this lower detection limit is approximately 200 ppm of chromatographable organics.

The GC specifications used in the TCO analysis are described below. A Hewlett-Packard GC Model 5840A flame ionization detector with automatic or hand injection was used. The column was glass 1.83-m long and 0.049-cm OD) packed with 10 percent OV-101 on 100/120 Supelcoport. Operation was 30° C isothermal for six minutes then programed to 20° C/minute followed by a 10 minute hold at 250° C. A helium carrier gas was used.

The calibration for TCO is based on the total peak area of a series of hydrocarbons. Three compounds, each in methylene chloride, were injected into the GC, octane (C8), dodecane (C12), and hexadecane (C16). Solution concentrations used were 30, 60, 120, 240, 320, and 400 g hydrocarbon/ml methylene chloride.

Gravimetric Organic Analysis (GRV)--

ample preparation -- The soil was air dried overnight.

Digestion or extraction -- A weighed sample of about 100 g was transferred to a Soxhlet thimble. An extraction with 400 ml of methylene chloride was conducted for 24 hours in a Soxhlet apparatus. The rationale for the use of methylene chloride as an extracting medium was the same as that described under TCO.

After extraction the final volume of methylene chloride was measured for use in the final concentration calculations. Drying of the methylene chloride extract was accomplished through a Na_2SO_4 column and concentrated via Kuderna-Danish to 10 to 25 ml.

Analytical technique -- The GRV procedure is a quantitative analysis of non-volatile components (materials above 300° C boiling point range). Arthur D. Little, Inc. studies using model compounds have shown that n-hexadecane (b.p. 303° C) defines a reasonable break point between TCO and GRV range materials. At least 10 mg of sample is weighed to a precision of ±0.1 mg. Sample and tare weights should be obtained by drying to "constant weight" (±0.1 mg) in a desiccator over silica gel or Drierite. This residual weight is defined as the GRV fraction. The practical detection limit is on the order of 0.1 mg in the one ml sample taken for GRV analysis. This corresponds to one mg total in the 10 ml sample extract. Based on the use of about 400 ml of methylene chloride per 100 g soil this lower detection limit is about 400 ppm of gravimetrically determined organics in a soil sample.

Organic Fractions--

Sample preparation -- The soil was air-dried overnight.

Digestion or extraction -- A soil or waste/soil sample was extracted with methylene chloride and dried then concentrated as described previously for both TCO and GRV. Silica gel (Davison 60-200 mesh, grade 950) was activated at 110° C for at least two hours. A slurry of 6.0 g of silica gel in pentane was packed into a 10 mm (ID) x 200 mm length liquid chromatography column. When the column was fully prepared the pentane level in the column was allowed to drop to the top of the silica bed so that the sample could be loaded for subsequent chromatographic elution. After packing the silica gel column, 3 g ±0.2 g of clean sodium sulfate was added to the top of the column. The concentrated methylene chloride extract was solvent exchanged with three successive one ml aliquot of cyclopentane. This cyclopentane extract was then transferred to the top of the silica gel column.

Analytical technique -- With the total organics extracted by methylene chloride from a soil or waste/soil sample now present on a silica gel column, it is possible to fractionate these organics. A liquid chromatographic separation is used, selecting for the polarity of compounds present. This is a low-resolution technique that has been demonstrated at Arthur D. Little to provide reliable separation of organic components into three classes as indicated below:

LCH: aliphatic hydrocarbons

LCA: aromatic hydrocarbons

LCX: polar organics (oxygenates, amines, etc.)

The elution sequence used in this program was as follows:

LCH: 5 ml pentane

LCA: 10 ml each, sequentially, of 20 percent methylene chloride in pentane; 50 percent methylene chloride in pentane; and methylene chloride

LCX: 10 ml each sequentially, of 5 percent methanol in methylene chloride; 20 percent methanol in methylene chloride, and 50 percent methanol in methylene chloride.

Each of the three fractions was then analyzed for TCO and GRV as described above. The sum of the respective TCO and GRV is thus the total organics in each of the three fractions. The LC procedure was originally scaled for 15 to 100 mg samples. However the total amount of material available from some samples in this project was less than 10 mg. Quantitative recovery from the column was 70 to 100 percent when samples containing about 10 mg or more of TCO plus GRV organics were used, but <50 percent for very small samples.

Polynuclear Aromatics--

Sample preparation -- The sample of soil was air dried overnight.

Digestion or extraction -- The total organic extract with methylene chloride, described under the TCO section, was used with water removal on a Na_2SO_4 column. A silica gel clean-up procedure described as a part of the organic fractions was used on the methylene chloride extract. This procedure is Method 610 (U. S. EPA, 1982).

Analytical technique -- Determination of specific polynuclear aromatics was with a high pressure liquid chromatograph (pumps, automatic sampler and injector from Waters Assoc.; column and Perkin-Elmer detector from Schoeffel). The program used was isocratic elution for five minutes using 40 percent acetonitrile and 60 percent water. Then a linear gradient elution to 100 percent acetonitrile was used over a 25 minute period. The flow rate was 0.5 ml/min.

Organic Carbon--

Sample preparation -- The soil or waste/soil complex was carried to dryness at 105° C. The material was sieved through a 100-mesh screen. Data are reported on a basis of dry soil or soil/waste mixture. No preparation was done on liquid runoff samples.

Digestion or extraction -- A weighed sample was placed in an ampule to which was added 6 percent (v/v) phosphoric acid solution. An approximate ratio of one ml acid to 50-100 mg of carbon projected in the sample was used. Two ml of water were added and allowed to wash the ampule walls. Aluminum foil was used to cover the ampule and allowed to stand for 30 minutes allowing time for the bicarbonate and carbonate to be converted to carbon dioxide. Two hundred milligrams of $K_2S_2O_8$ was added to the ampule with a dipper followed by two ml of distilled water to wash the ampule walls. A purge was made of the ampule for six minutes. Distilled water (CO_2-free) was used to wash sediment from the purge tube into the ampule at which time the ampule was sealed. The conversion of organic carbon to carbon dioxide occurs in the sealed ampule over four hours at 130° C in an autoclave.

Analytical technique -- The sealed sample was placed in an Ampule Analyzer Unit (Oceanography International Corp.). This method is an approved standard by Method 415.1 (U. S. EPA, 1979).

Oil and Grease--

Sample preparation -- In a 150 ml beaker a waste/soil sample was weighed to yield about 20 g ± 0.5 g. A separate determination of moisture content was made so that the results could be reported on a dry solids basis. The sample was acidified to pH 2.0 (generally 0.3 ml of concentrated HCl). To the sample was added 25 g $MgSO_4$-H_2O, and the mixture stirred to a smooth paste and spread on the sides of the beaker to facilitate subsequent removal. The mixture was allowed to stand for 15 to 30 minutes to solidify. For water samples the runoff liquid (whether filtered in the field or not) was analyzed with a method appropriate to surface water testing. No preparation was used except acidification to pH <2.0 for preservation prior to analysis.

Digestion or extraction -- The solids were removed and ground in a porcelain mortar. The powder was added to a paper extraction thimble. Beaker and mortar were wiped with small pieces of filter paper moistened with solvent and added to the thimble. Glass wool or small glass beads are used to fill the thimble. Extraction in a Soxhlet apparatus, using trichlorotrifluoroethane was conducted at a rate of about 20 cycles per hour for four hours. If any turbidity or suspended matter was present in the extraction flask, these were removed by filtering through grease-free cotton into another weighed flask. The flask and cotton were rinsed with solvent. Distillation of the solvent from the extraction flask in water is conducted at 70° C. The flask was placed in a water bath at 70° C for 15 minutes and air was drawn through it using an applied vacuum for one minute. The flask was then cooled in a desiccator for 30 minutes and weighed. For the water samples approximately one liter of sample was added to a separatory flask with about 30 ml of fluorocarbon-113 (1,1,2 trichloro- 1,2,2 trifluoroethane) and after intimate contact the solvent was removed to a boiling flask. The solvent containing the oil from a liquid sample was connected to a distillation head and the flask immersed in a 70° C bath. After the fluorocarbon solvent was removed the residue weight was determined.

Analytical technique -- The oil and grease were determined as the weight gain of the flask having gone through the above steps. When divided by the dry weight of the original sample a result is obtained. The reagents, apparatus, and procedures used for the oil and grease analysis were according to Method 503D of Standard Methods for Analysis of Water and Wastewater (American Public Health Association, 1971). For water samples the method used was according to approved EPA method 413.1 (U.S. EPA, 1979).

Inorganics

Soil Texture--

Sample preparation -- Material received from the field or greenhouse was air dried.

Analytical technique -- A physical sizing test with nested sieves was used to determine the fraction of each sample in each of the respective classification sizes down to 200 mesh. For the smaller silt and clay fractions an hydrometer test is used. The ASTM D 2487-69 test method was used.

Soil Solution Conductivity--

Sample preparation -- The sample was thoroughly mixed and sieved through a No. 8 sieve. If the sample was too moist to be sieved, it was first dried in a 60° C oven and then crushed. Rocks are excluded. The sample was quartered or subsampled to yield about 1,300 g.

Digestion or extraction -- Based on the dry matter percentage a 1:5 soil to water extract was prepared. This suspension was used as is.

Analytical technique -- A calibrated conductivity probe and meter was used (initially Thomas 275 meter then YSI 32 meter).

Total Nitrogen--

Sample preparation -- The waste/soil samples were air dried, then crushed to pass through a No. 10 sieve. For water samples the liquid material was mixed well and used as is.

Digestion or extraction -- A soil or waste/soil sample of 0.5 g was placed in a 100 ml Kjeldahl flask with 0.5 g of chromium powder. Water (10 ml) was mixed with and allowed to contact the sample for 10 minutes then two ml of concentrated HCl were added and allowed to stand for 5 to 9 minutes. The mixture in the flask is put on a hot plate for about 3 to 5 minutes then allowed to cool. To the cooled mixture 3.5 g of Kelpack and 10 ml of concentrated sulfuric acid were added and then heated for about 20 minutes. The digestion continues until dense white fumes clear the flask (15 to 20 minutes). After cooling, water was added to bring the volume to 110 ml. An aliquot of 10 to 20 ml was filtered to obtain a clear digestate. The digestate was quantitatively diluted and a three ml aliquot taken for analysis.

Analytical technique -- The dilute sample (three ml) was added to four ml of basic phenol solution and mixed. To this 10 ml of NaOCl solution (1.05 percent) was added, mixed, and allowed to stand for 30 minutes. An aliquot was taken and placed in a spectrophotometer for an absorption reading at 630 nm. The result was compared to a standard curve generated from NH_4 solutions with either sample digestate or water (Bremner, 1965).

Extractable Phosphorous--

Sample preparation -- The same procedures as for total nitrogen were used. For water samples the liquid was mixed well and used as is.

Digestion or extraction -- An extracting solution was prepared as developed by the International Soil Fertility Evaluation Project (International Soil Fertilizer Project Report, 1976). ISFEP solution begins with dissolving 210 g $NaHCO_3$, 37.2 g disodium EDTA, 3.7 g NH_4F, and 0.5 g dissolved superfloc 127 in seven liters of water. This is diluted to 10 liters and the pH adjusted to 8.4 with concentrated NaOH. A soil sample (2.5 ml) was added to 25 ml of ISFEP extracting solution and stirred at 400 rpm for 10 minutes and filtered.

Analytical technique -- Color development reagents (A and B) were prepared. Reagent A is one g antimony potassium tartrate to about 400 ml of water in a one liter volumetric flask. While mixing, concentrated sulfuric acid (150 ml) is added slowly and allowed to cool. Ammonium molybdate is dissolved in 300 ml of water and added to the cooled antimony solution. The mixture is diluted with water to one liter. Reagent B is made by dissolving one g of gelatin in 100 ml of hot water. In a one liter volumetric flask 150 ml of Reagent A, 500 ml of water, and the dissolved gelatin are added and mixed. Ascorbic acid (one ml) is added and the solution diluted with water to one liter. An aliquot of one ml was taken from the dilute, filtered digestate and added to nine ml of water and 10 ml of Reagent B. The mixture was allowed to stand for 40 minutes to assure complete color development. A subsample was measured for absorbance at 680 nm on a spectrophotometer. The result was determined from a calibration curve (based on phosphate added to digestate)(Olsen and Dean, 1965).

pH--

Sample preparation -- An as is soil volume of about 10 ml was added to 25 ml of water and the mixture stirred for 10 minutes. After standing for 30 minutes the mixture was stirred again for two minutes. For the water samples the liquid was mixed well and used directly for testing.

Analytical technique -- The pH electrode was placed in the solution and a pH reading made.

Ca, Mg, Na, NH_4, and Exchangeable Acidity--

Sample preparation -- The same procedures as for total nitrogen were used. For the water samples the liquid was filtered prior to analysis.

Digestion or extraction -- A replacing solution method was used to measure these parameters as well as the cation exchange capacity which was derived from these results. The replacing or extraction solution was 1 N KCl. A 2.5 g sample of the soil was added to 25 ml of 1 N KCl and the mixture stirred for 10 minutes and then filtered.

Analytical technique -- The exchangeable acidity was determined from 10 ml of soil filtrate plus 15 ml of water. With 3 to 4 drops of phenolphthalien indicator, the sample was titrated with 0.1 N NaOH to reach the endpoint corresponding to an equal number of meq of exchangeable acidity/100 ml of soil.

For NH_4 three ml of soil filtrate were added to four ml of basic phenol solution. To this 10 ml of NaOCl solution was added and allowed to stand for 30 minutes. The reading on a colorimeter at 630 nm and an appropriate calibration curve were used to arrive at the sample determination.

The cations Ca, Mg, and Na are determined by adding one ml of soil filtrate to nine ml water and then 10 ml of Lanthanum solution (59 g La_2O_3 and 200 ml concentrated HCl to five l of solution). An aliquot of this mixture is put in an atomic absorption device and readings made for Ca, Mg, and Na. The results are determined from a calibration curve for each cation. If the solution is greater than 200 ppm Ca, 50 ppm Mg, or 30 ppm Na a dilution is performed.

Potassium (K)--

Sample preparation -- The same procedures as for total nitrogen were used.

Digestion or extraction -- The same procedures as for total phosphorous were used.

Analytical technique -- A one ml aliquot of the filtrate was added to 19 ml of water and the concentration determined from readings on an atomic absorption device. Dilution was necessary for K concentrations greater than 40 ppm.

Cation Exchange Capacity (CEC)--

Analytical technique -- The CEC was calculated as the summation of exchangeable cations and exchangeable acidity, each expressed in meq/100 g soil.

Total metals (Fe, Mn, Co, Mo, Al, As, Se, Cd, Cu, Cr, Ni, Zn, Pb, Sr, V, Ba, B, Ti)--

Sample preparation -- The soil samples were analyzed on an air dry basis (0 to 7 percent moisture) and the results reported accordingly. For the water samples the liquid was filtered through a 0.45-um membrane filter and then the pH lowered to <2.0 with concentrated redistilled HNO_3 as a preservation method. Vegetation samples were ashed at 450° C using standard AOAC procedure 3-008 (Association of Official Agricultural Chemists, 1970).

Digestion or extraction -- The standard method (SW846, No. 3050, U.S. EPA, 1982), total HNO_3 extractable metals from solids or sludges was used. Vegetation was analyzed using the same procedure as for soils.

Analytical technique -- An aliquot of the digestate was analyzed by induction coupled argon plasma (Jarrell Ash Model 975, Mark II system).

Soluble Metals--

Sample preparation -- The same procedures as for total metals were used.

Digestion or extraction -- A 10 g soil sample was mixed with five ml of RO water and shaken for one hour yielding a 1:5 solution. The mixture was filtered using #42 filter paper and analyzed immediately. This follows the standard procedures of Methods of Soil Analysis, Part 2, 10-2.3.2 (Black 1965).

Analytical technique -- The filtrate was analyzed in the same manner as the digestate from the total metals analyses. This follows the standard procedures (SW846 No. 6010, U.S. EPA, I982).

DATA MANAGEMENT

Analytical data generated by each of the laboratories involved in this study were scanned for errors upon receipt and the responsible laboratory notified for clarification or re-analysis.

In the early phases of the project (the first two sampling periods) all data were entered on coding forms and key-punched to cards. After the data were stored on magnetic tape they were again checked against the original data as received from the laboratories. Early summaries of the data were prepared for Committee review using the Statistical Analysis System (SAS).

The data for the last three sampling periods were scanned for errors and then entered directly from the data sheets provided by the laboratories into a personal computer (IBM PC) data base and spread sheet program. The data were then checked for entry errors against the original data sheets. Data from the earlier sampling periods were merged into the personal computer files to make a complete set. All subsequent data summaries were prepared directly from the merged data set. The data files were maintained on a 20 mega-byte hard disk with magnetic tape back-up.

Over 18,000 data values were generated by this study and data management was carefully maintained to insure integrity of the data. All data transfer to other files was done directly program to program so there was little chance for introduction of error due to hand transcription. All graphs were generated from direct transfer files as were the data tables in this report.

QUALITY ASSURANCE AND QUALITY CONTROL

Four chemistry laboratories performed analytical work for this project. All four labs follow EPA prescribed Quality Assurance and Quality Control (QA/QC) procedures for running duplicates, blanks and spikes (U. S. EPA, 1979) Quality control reference samples from EPA are tested whenever available. Three of the labs have internal QA/QC procedures that exceed EPA requirements. These are described briefly below.

Law Environmental Services, responsible for running total organic carbon, oil and grease and conductivity maintains a program for data precision, accuracy and completeness. Each lab analyst's work is reviewed by another chemist to detect false assumptions in the method application, incorrect calculations or transcription errors. A system of internal audits by Division and Corporate QA Managers is maintained in which unannounced reviews of the equipment calibration program and QA reporting and documentation program are performed.

The EPA Robert S. Kerr Laboratory in Ada, Oklahoma performed all of the metals analyses. Analytical instruments are calibrated every day for metals analyses. The EPA QC reference samples for minerals and trace metals and sample blanks are run at the beginning, in the middle and at the end of each analytical run. Duplicate samples are run for every two to ten samples depending on expected sources of error or interference. For this study duplicates were run every five to seven samples. The detection limits are given in Table 3-3.

All organic analyses using liquid and gas chromatography were performed by Arthur D. Little, Inc. For the quantitative HPLC analyses, peak identifications were made by analyzing both the actual sample extract and an aliquot of the sample extract spiked with each of the PNAs and comparing the chromatograms. Once identifications were made the concentrations were calculated using the external calibration method. Due to the large amount of extractable organics present in the samples both chromatographic blanks (blank gradients) and solvent blanks were regularly inserted between samples to minimize sample carryover.

The coefficients of variation for many of the individual PNAs were determined for greenhouse soil sample LA204 from the June, 1983 sampling (Appendix C). Triplicate injections were made on four separate days. Quantification was on an external calibration basis. The results obtained for the analytical finish portion of the analysis are summarized in Table 3-3.

Limits of detection for analyses performed by all laboratories are presented in Table 3-3. Detection limits indicated are theoretical limits when adequate sample is available and excessive interference is not present. For oil and grease and several PNAs sample volumes were occasionally insufficient to achieve the indicated detection limits. For certain metals analyses interferences caused detection limits to vary somewhat. These variations were not significant in terms of interpreting the analytical data.

Sources of Error

Because of the expense associated with analysis of the large number of samples and parameters generated by a project of this type, a decision was made at the outset to opt for more sites and parameters analyzed without analytical replication rather than for fewer sites and parameters with analytical replication. To assure some error reduction by replication all treatments were replicated as previously described. Samples were uniformly composited from each treatment's replicates prior to analysis. Thus, there is no opportunity to statistically compare analytical results nor to eliminate apparent errors due to mislabeling, laboratory mixup or error. Another potential source of error may be the sampling of a "hot spot" in one replicate that overshadows the other replicate's composites.

All the data reported in Appendix A are results of composite sample analyses. At the last sampling event (June 1984 in the greenhouse and November 1984 in the field) sufficient sample was taken to complete all the total extractable soil metals and soluble soil metals analyses on non-composited samples as well as the normally prepared composite samples. These data with means and standard deviations are reported in Appendix B. Comparison of these data with the concurrent composite sample analyses provide an indication of the variability that might be expected.

TABLE 3-3. ANALYTICAL LIMITS AND EXPECTED COEFFICIENT OF VARIATION

	Soil		Runoff Liquid
	Lower Detection Limit	Expected Coeff. of Variation	Lower Detection Limit
	mg/kg	%	mg/l
Total organic carbon, TOC	200	---	1
Oil and Grease, O&G	200	---	5
Total chromatagraphable organics, TCO	5	---	0.25
Aliphatic fraction of TCO, LCH	125	---	6.2
Aromatic fraction of TCO, LCA	150	---	7.5
Polar fraction of TCO, LCX	150	---	7.5
Gravimetric organics, GRV	50	---	2.5
Aliphatic fraction of GRV, LCH	125	---	6.2
Aromatic fraction of GRV, LCA	150	---	7.5
Polar fraction of GRV, LCX	150	---	7.5
Anthracene, AN	0.4	---	0.02
Benz(a)anthracene, B(a)A	0.02	0.5	0.001
Benzo(b)fluoranthene, B(b)F	0.04	4.3	0.002
Benzo(k)fluoranthene, B(k)F	0.04	14.2	0.002
Benzo(a)pyrene, B(a)P	0.1	8.1	0.005
Dibenz(a,j)acridine, DB(a,j)AC	0.04	6.9	0.002
Dibenz(a,h)anthracene, DB(a,h)A	0.15	15.3	0.008
Indenopyrene, IP	0.15	---	0.008
Pyrene, P	0.5	---	0.03
Dibenzofuran, DBF	1.4	12.2	0.07

TABLE 3-3. (continued)

	Soil Lower Detection Limit	Runoff Liquid Lower Detection Limit
	mg/kg	mg/l
Total Kjeldahl nitrogen, TKN	1	0.05
Exchangable phosphorus, Exch. P	1.0	0.01
Calcium, Ca	0.1	0.1
Magnesium, Mg	0.1	0.1
Sodium, Na	0.1	0.1
Ammoniumn, NH4-N	1.0	0.01
Potassium, K	0.2	0.2
Iron, Fe	0.1	0.1
Manganese, Mn	0.01	0.01
Cobalt, Co	0.01	0.01
Aluminum, Al	0.1	0.1
Arsenic, As	0.03	0.03
Selenium, Se	0.03	0.03
Cadmium, Cd	0.003	0.003
Copper, Cu	0.01	0.01
Chromium, Cr	0.01	0.01
Nickel, Ni	0.01	0.01
Zinc, Zn	0.01	0.01
Lead, Pb	0.02	0.02
Strontium, Sr	0.01	0.01
Vanadium, V	0.01	0.01
Barium, Ba	0.01	0.01
Boron, B	0.01	0.01
Titanium, Ti	0.1	0.1
Beryllium, Be	0.003	0.003
Silver, Ag	0.01	0.01
Thallium, Tl	0.02	0.02

CHAPTER 4

RESULTS AND DISCUSSION

The concept of closure implies that without continued waste applications a land treatment site undergoes further assimilation of chemical constituents. The assimilation leads to a return to conditions resembling surrounding areas where subsequent environmental impact is minimal. The concern is on achieving site conditions in which environmental effects are negligible and would be expected to remain so during future land use. This study of closure was aimed at establishing the changes which occur in typical petroleum landfarm soils without further waste addition and evaluating the potential for environmental impact from a closed landfarm.

As described in the report introduction the basis for these studies was the evaluation in the greenhouse of four landfarm waste/soils and the respective control soils. The experiments spanned two years of closure-like conditions. One waste/soil was also the subject of similar sampling and analysis in the field, so that the relative behavior in the greenhouse and the field could be directly judged. The following discussion focuses first on the initial conditions and behavior of waste constituents in the four separate petroleum waste/soil mixtures from actual refinery landfarms (sites OP, OT, TX and WA). Then a comparison is made between site OT soil behavior in the greenhouse and the field. Finally the environmental impact of the field site for such factors as vegetation uptake, rainfall runoff, and leaching during the two year closure period are assessed. Since rainfall runoff phenomena are heavily dependent on the availability of waste constituents in the surface soil, this is another reason for the extensive study of this zone in these greenhouse and field experiments.

BEHAVIOR OF AGGREGATE ORGANICS

Three measures of aggregate organic concentrations were used to establish the initial conditions and closure period behavior;

1. total organic carbon (TOC),
2. oil and grease (O&G), and
3. total chromatographable plus gravimetric organics (TCO+GRV).

These characteristics (TOC, oil and grease, TCO+GRV), represent three different extraction chemicals and techniques, namely, six percent phosphoric acid shaken for 30 minutes, 1,1,2-trichloro-1,2,2-trifluoroethane for four hours in Soxhlet device, and methylene chloride for 24 hours in a Soxhlet device, respectively.

The control soils at each location were also analysed for the organic parameters, Figures 4-1 to 4-3 (initial conditions 6/82). The data from which these graphs were derived are in Appendix A.

For the greenhouse waste/soil mixtures the TOC, oil and grease, and TCO+GRV were relatively similar among the four landfarm sites (within 2-fold) and not greatly dissimilar among the separate organic parameters (within 2- to 3-fold). This was surprising in light of the variety of landfarm practices, Table 3-1, and the nature of the analytical procedures. The advantage of this similarity of the initial conditions for the several organic parameters is that the subsequent behavior of the waste/soil mixtures are roughly comparable, and therefore reflective of refinery waste land treatment conditions.

The oil and grease and TCO parameters evidenced the greatest variation among the four waste/soil mixtures, with TOC and TCO+GRV being quite similar. The TCO as a small fraction of the group TCO+GRV is a measure of smaller chain length organics. However TCO is a very small percentage of TCO+GRV and the other measures of aggregate organics and thus the more erratic TCO behavior is not a major factor in the overall organics decomposition pathway. The C:N for the treated soils was in the range of 21:1 to 43:1, indicating the effect of petroleum wastes, while the control soils were 9:1 to 24:1.

The aggregate organic parameters were used in an effort to ascertain the changes in organic content of the surface soil over the two-year closure simulation. For all cases, the soils were kept under greenhouse conditions and the surface 15 cm sampled as a function of time. A general pattern is seen throughout these data, Figures 4-1 to 4-3. A reduction in organic level occurs in the early periods (June 1982 to November 1982 and November 1982 to June 1983) as evidenced by oil and grease and total organic carbon.

Following that time there are lesser decreases and a certain oscillation with some increasing concentrations. No consistent organics concentration differences were found in the waste/soil mixtures between pots with or without vegetation over the course of the experiments.

These trends are illustrated in Figures 4-1 to 4-3, however can additional means of data analysis was also utilized. For the

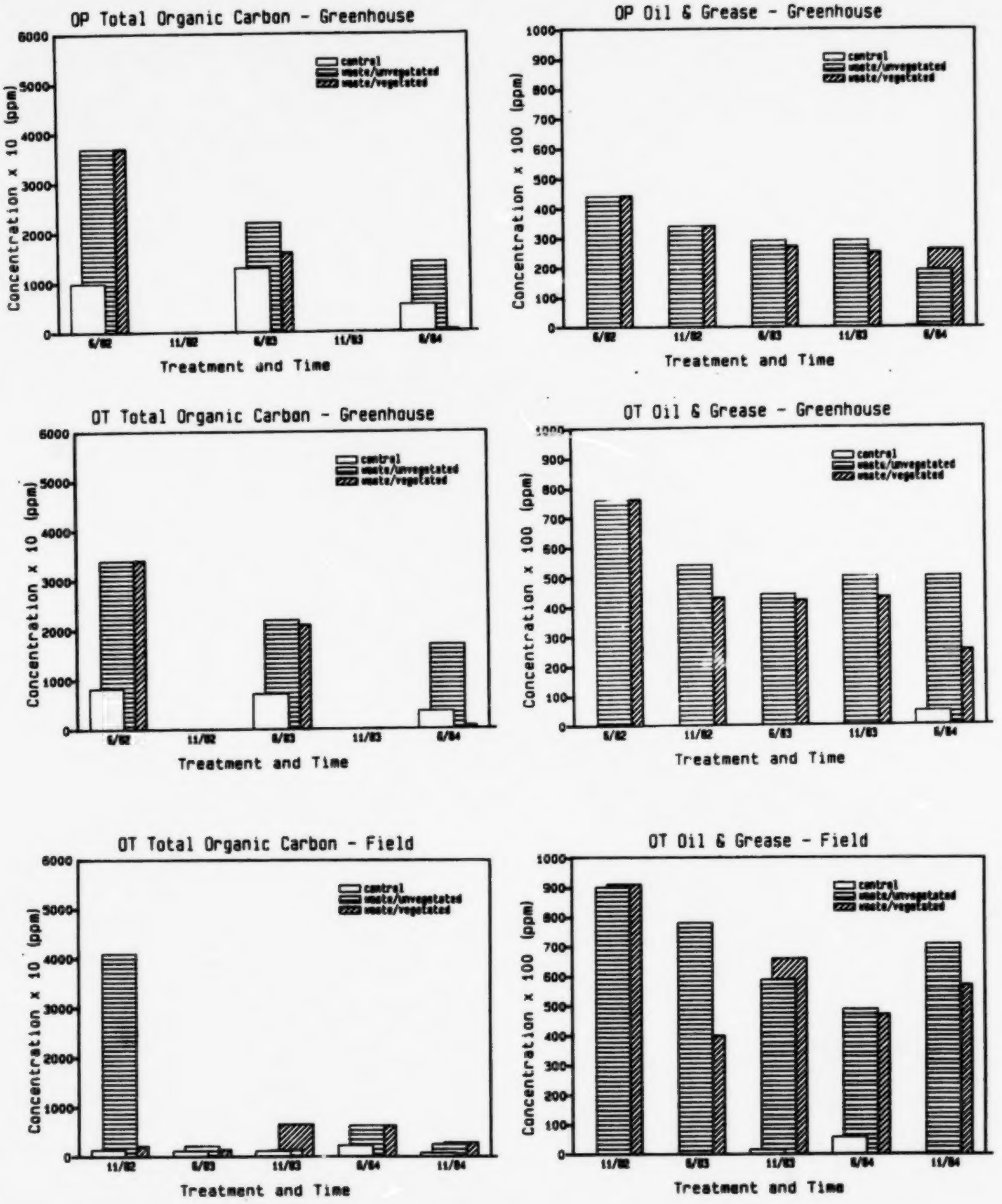


FIGURE 4-1. PLOTS OF TOTAL ORGANIC CARBON (TOC) AND OIL AND GREASE FOR SITES OP/GREENHOUSE AND OT/GREENHOUSE AND FIELD

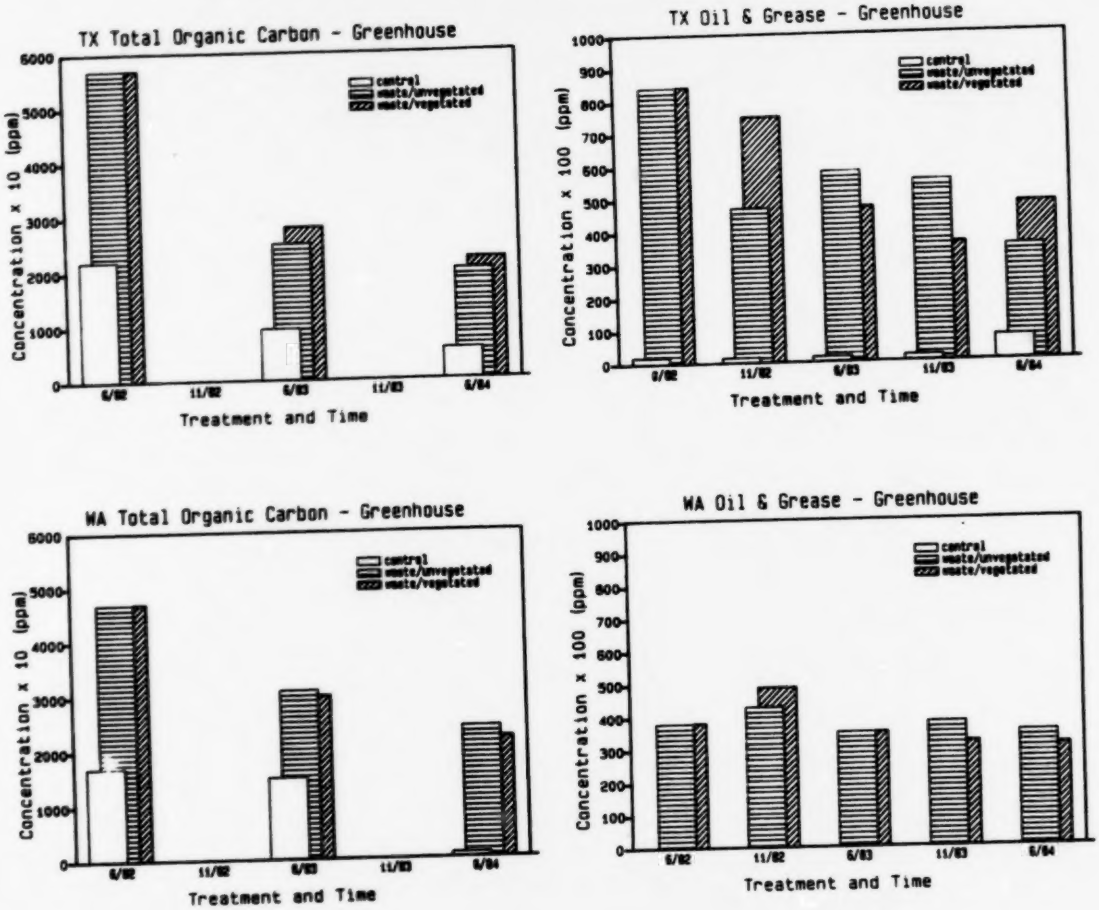


FIGURE 4-2. PLOTS OF TOTAL ORGANIC CARBON (TOC) AND OIL AND GREASE FOR SITES TX/GREENHOUSE AND WA/GREENHOUSE

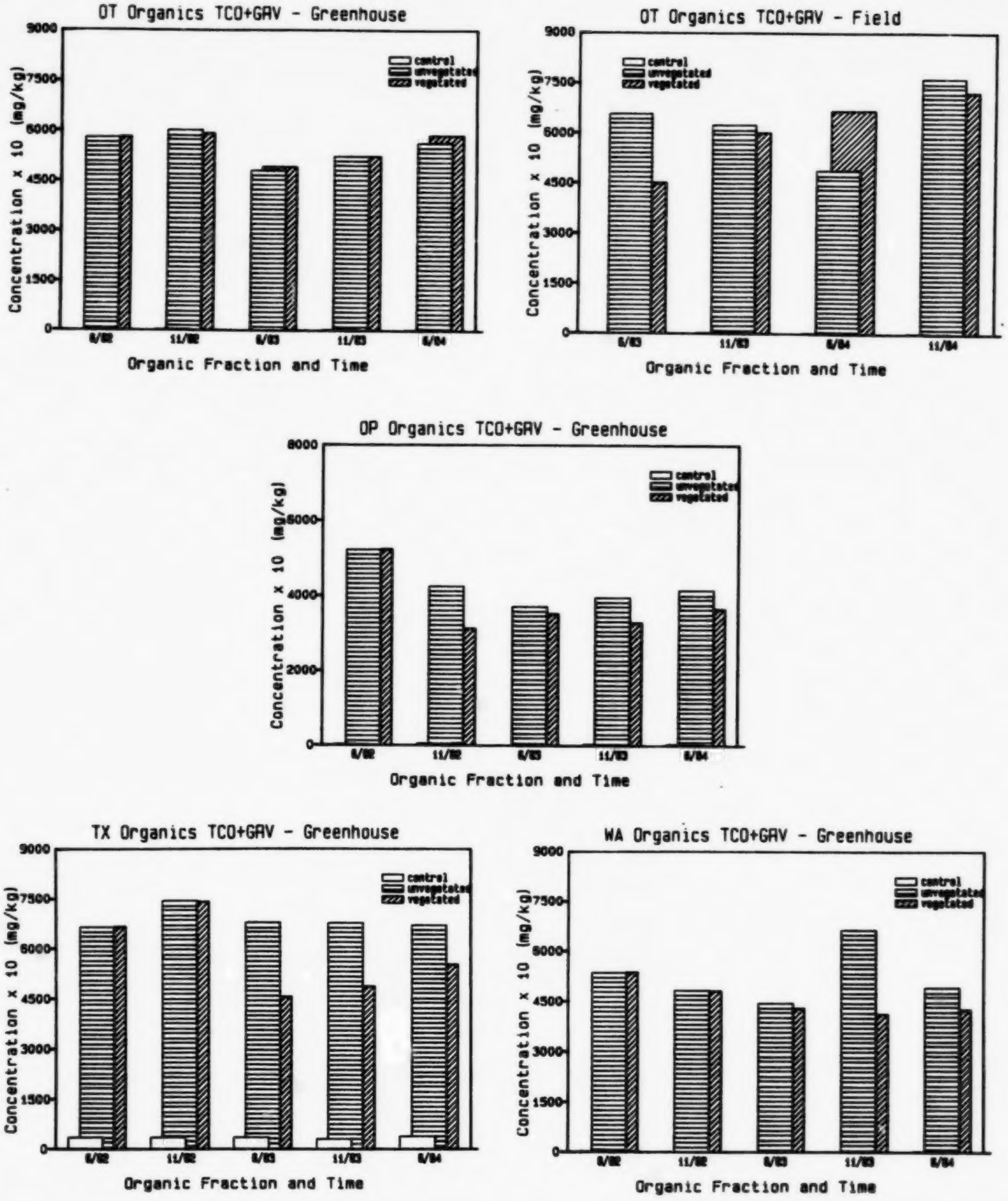


FIGURE 4-3. PLOTS OF TCO & GRV FOR EACH SITE

periods between sampling the mass of organic loss was calculated for each of the aggregate organic parameters, Table 4-1.

The oil and grease mass loss was largest in the first six months then decreased in the second six months. The final year achieved relatively low mass losses. The WA landfarm soil was an exception with negative or very low losses over the entire two years. Greenhouse observations indicated substantial hydrophobicity with the WA waste/soil. At times water ponded when applied with conditions generally unfavorable for rapid decomposition. These WA waste/soil conditions would have been helped by substantial fertilization and tillage, but due to the decision to maintain consistent and minimal disturbance conditions among the various landfarm pots, these special techniques were not used.

The TOC concentration was measured less frequently than oil and grease (O&G). For the first year, the TOC loss was approximately the same as the mass loss of O&G averaged over the first year.

In the second year the TOC loss was lower and in some cases negative indicating an asymptotic behavior.

Only for the waste/soil mixture from site OP did the TCO+GRV (methylene chloride extract) behave in a quantitatively similar manner for mass loss to the other organic parameters. The TCO reductions were erratic over the first and second years for all the waste/soil types, and are not given in Table 4-1.

The decrease during the first year, followed by an asymptote in aggregate organic parameter concentration, is characteristic of general organic behavior in soil. However the basis for the organics asymptote could not be determined from this research. The asymptote was in all cases considerably above the level of control soils. However when any organic source is added to soils the result is a similar long term increase, above the natural soils, in organic level representing improved soil properties of tilth, drainage, and soil aggregate formation. In the case of the asymptotes found in these studies there are several possible explanations. The first was that a nitrogen (or some other nutrient) limitation was reached which resulted in a slowing of the decomposition process. A second explanation was that the asymptotic level represents stable organics which are less prone to decomposition. These stable organics could be microbial end-products and materials characteristic of naturally high organic soils or could be stable constituents originally present in the refinery waste.

In addition to the absolute levels of organic paramters it is important to judge the relative potential environmental impact. This was done by a quantitative comparison of aggregate

TABLE 4-1. RATE OF MASS LOSS (mt/ha/yr) FOR AGGREGATE ORGANIC PARAMETER OVER THE TWO YEAR CLOSURE PERIOD

Parameter and Location	Decomposition Interval			
	6/82- 11/82	11/82- 6/83	6/83- 11/83	11/83- 6/84
Oil&Grease				
OP	40 - 60	12	2	6
OT	44 - 66	25	(10)	16
OT-Field		62	(6)	28
WA	(10) - (15)*	16	0	4
TX	46	16	12	8
TOC**				
OP	<-------- 21 - 25 --------->		<----(3)------>	
OT	<-------- 12 - 14 --------->		<-----1------->	
OT-Field		42	<----17------->	
WA	<-------- 14 - 17 --------->		<----(6)------>	
TX	<-------- 19 - 23 --------->		<-----1------->	
TCO+GRV				
OP	20 - 30	10	2	(4)
OT	(4)	24	(8)	(10)
OT-Field			(12)	8
WA	12	6	(18)	16
TX	(14)	12	20	(6)

* Parentheses indicate increase in mass of aggregate organic parameter

** TOC waste/soil values corrected for respective control TOC values

organic levels in the waste/soil mixture to the respective control soil, Table 4.2. The higher this ratio the greater the likelihood of a significant difference from the control for such environmental impacts as runoff, crop uptake, and leaching. The actual differences in environmental impacts observed in these studies (described in a later section) can thus be judged against the magnitude of the concentration differences in the surface soil, Table 4.2. The aggregate organic parameters of O&G and TCO+GRV were typically several hundred fold of the control while TOC was 1.5 to 3.5-fold higher.

TABLE 4-2. COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTE/SOIL MIXTURES WITH CONTROL SOILS

Parameters	Ratio of Soil Concentration Waste/soils : Control Soils
Organics	
TCO+GRV	280 - 600**
O&G	20 - >760**
TOC	1.5 - 3.5
Inorganics	
Chromium, Cr	12
Zinc, Zn	8.6
Copper, Cu	7.1
Sodium, Na	4.4
Calcium, Ca	6.1
Strontium, Sr	3.5
Boron, B	3.5
Total Nitrogen, TN	3.3
Lead, Pb	3
Barium, Ba	2
Cadmium, Cd	2
Total Phosphorus, TP	1.6
Potassium, K	1.6
Titanium, Ti	1.3
Nickel, Ni	1.3
Aluminum, Al	1.2
Molybdenum, Mo	1.1
Vanadium, V	1.1
Magnesium, Mg	1
Cobalt, Co	1
Iron, Fe	0.9
Manganese, Mn	0.8

** These ratios appear large because control values are very small (Fig 4.1-4.3).

BEHAVIOR OF FRACTIONS OF THE TOTAL ORGANIC EXTRACT

The organic material extracted from the waste/soil mixtures was split into a group (TCO) with a boiling point generally lower than 303°C and a group (GRV) with a boiling point above this temperature. Each of these two groups was fractionated into the additional subcategories:

1. aliphatics (LCH),
2. aromatics (LCA), and
3. polar species (LCX).

Over the 22 months allowed for decomposition in the greenhouse study these fractions were analysed most frequently in the unvegetated treatments and at moderate frequency in the vegetated pots and controls. The results are depicted in Figures 4-4 to 4-13. The data are in Appendix A. The following discussion integrates the typical variability of these measurements and focuses on the major behavior exhibited by these aggregate organic compound fractions.

In the lower boiling group (TCO) the relative magnitude of the fractions was generally aliphatics > aromatics > polar species. An exception was the site OP waste/soil in which aromatics > aliphatics > polar species. The TCO fractions in control soils were always below detection and so it was not possible to determine the relative magnitude of these fractions in the absence of petroleum wastes. Examining the percentage loss in each separate waste/soil fraction (regardless of vegetation status) the aliphatics and aromatics decreased to about 10 to 30 percent of the initial levels, while the polar species were usually greater when compared to the initial levels. The decrease in aromatic and aliphatic fractions and corresponding increase in the polar fraction is not unexpected based on microbial stabilization. However it must be remembered that the TCO and respective fractions are a very small percentage of the total organics present, and so shifts in fractions may not be highly significant. The LCH and LCA fractions of the TCO in all waste/soil types decreased to the range of 200 to 900 mg/kg soil. This residual level of the fractions was still considerably above the background or control soil. Likewise, the TCO measured on the total organic extract was reduced to 300 to 1,300 mg/kg soil which remained well above that for the control soil. Since petroleum organics may be decomposed microbially, it is not unanticipated that there would be an increase in stabilized organics.

In the higher boiling group (GRV) the relative magnitude of the fractions was the same as that with the lower boiling point species, i.e. aliphatics > aromatics > polar species. Again, this characteristic of petroleum refinery sludge was different for the site OP waste/soil with aromatics > aliphatics > polar species. The few measurements of these fractions of the GRV on control soil indicated aliphatic > aromatic = polar species. In overall comparison the GRV fractions are 10 to 100-fold of the respective TCO fractions.

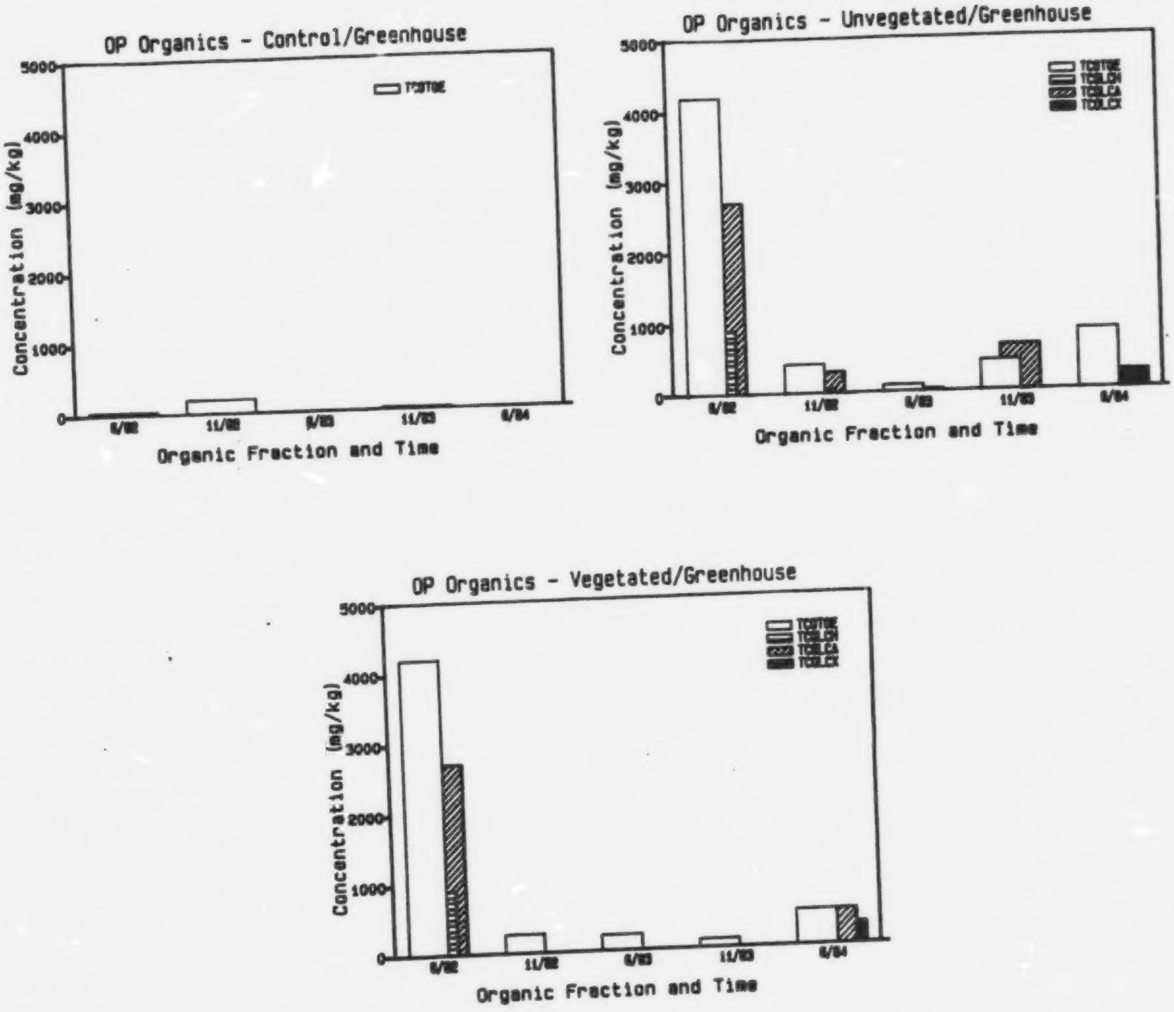


FIGURE 4-4. PLOTS OF TCO FRACTIONS FOR SITE OP

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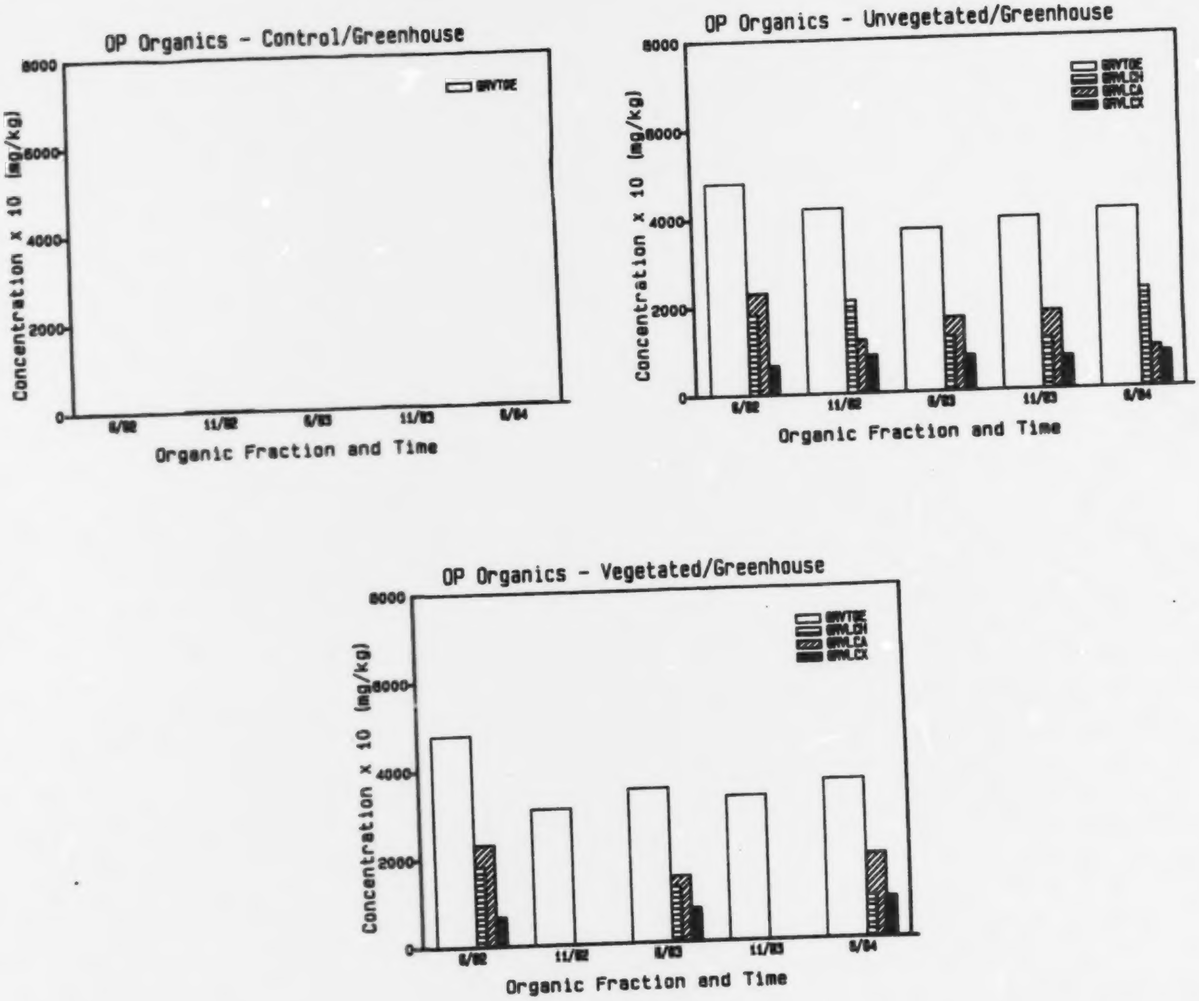

FIGURE 4-5. PLOTS OF GRV FRACTIONS FOR SITE OP

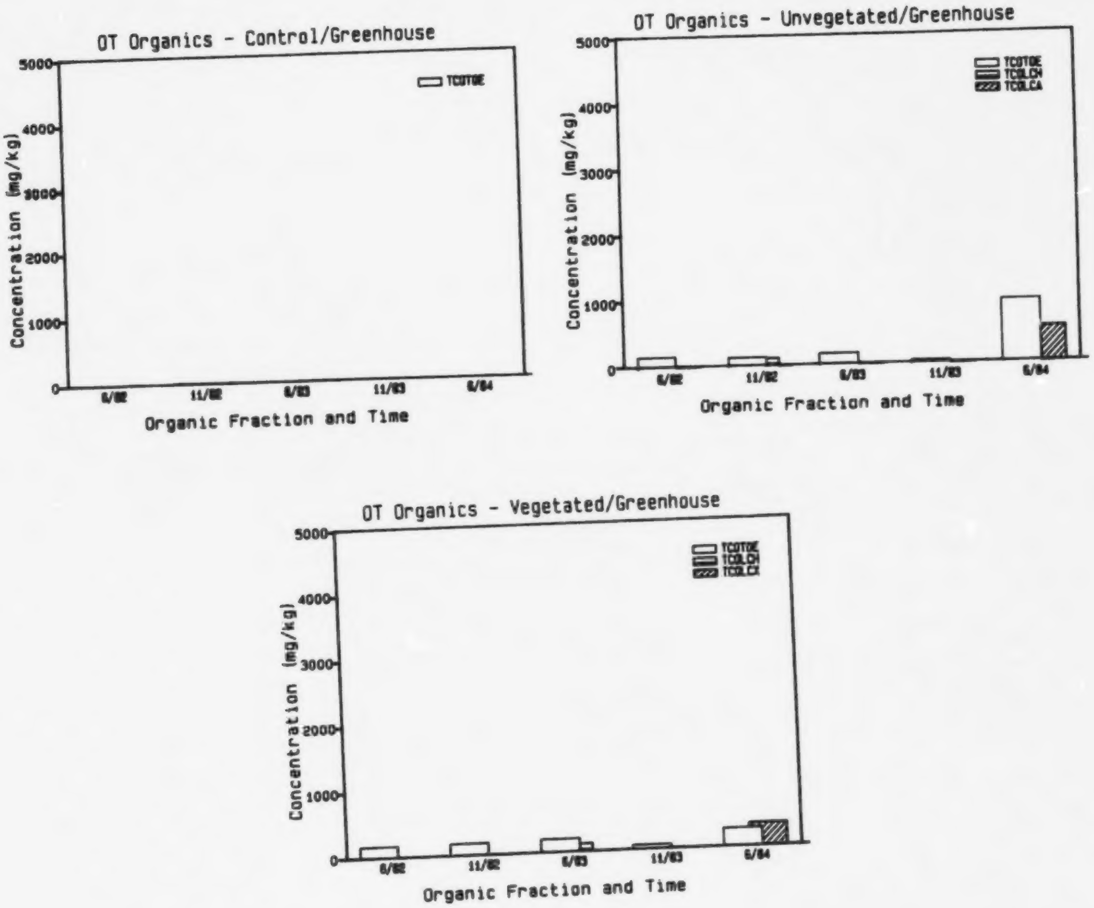

FIGURE 4-6. PLOTS OF TCO FRACTIONS FOR SITE OT/GREENHOUSE

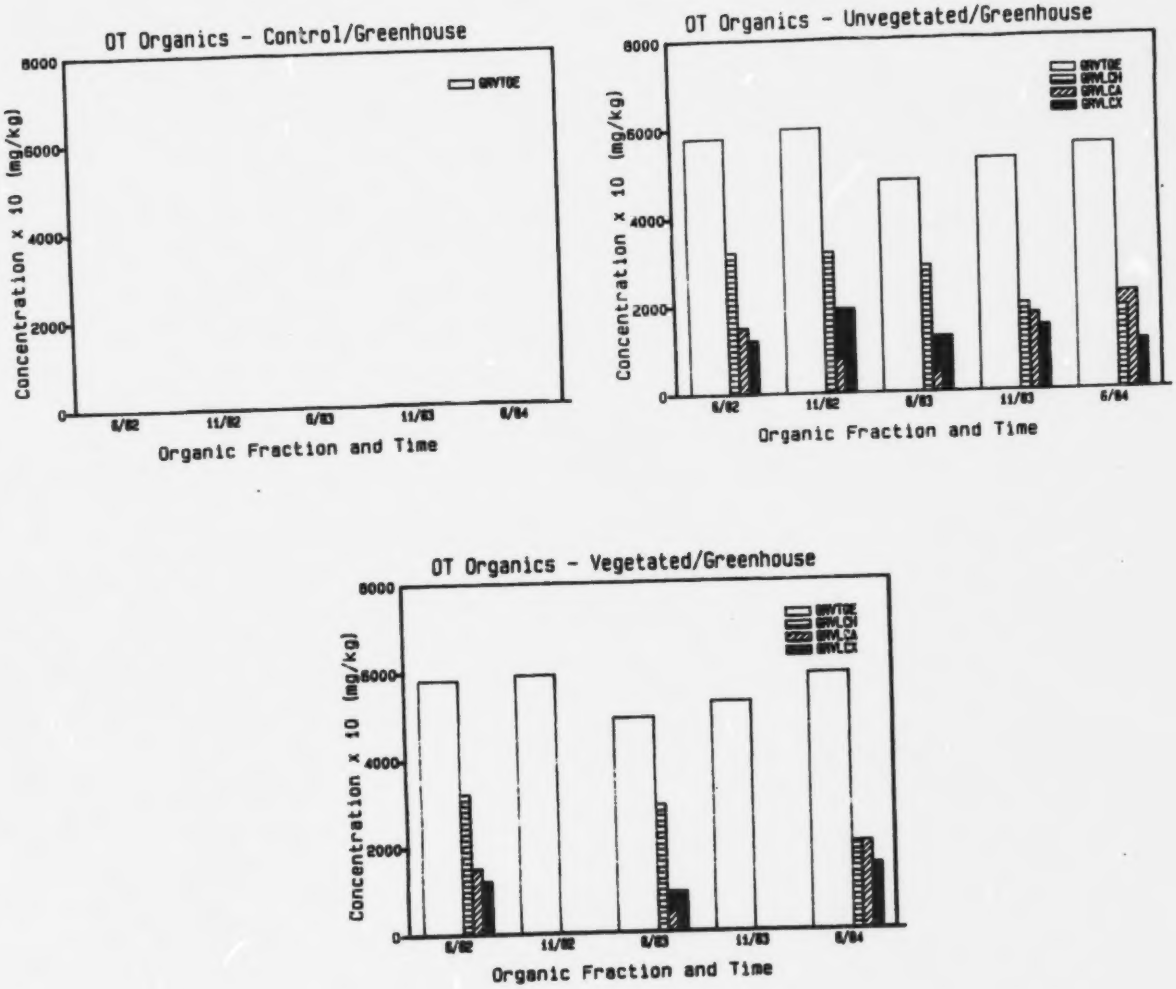

FIGURE 4-7. PLOTS OF GRV FRACTIONS FOR SITE OT/GREENHOUSE

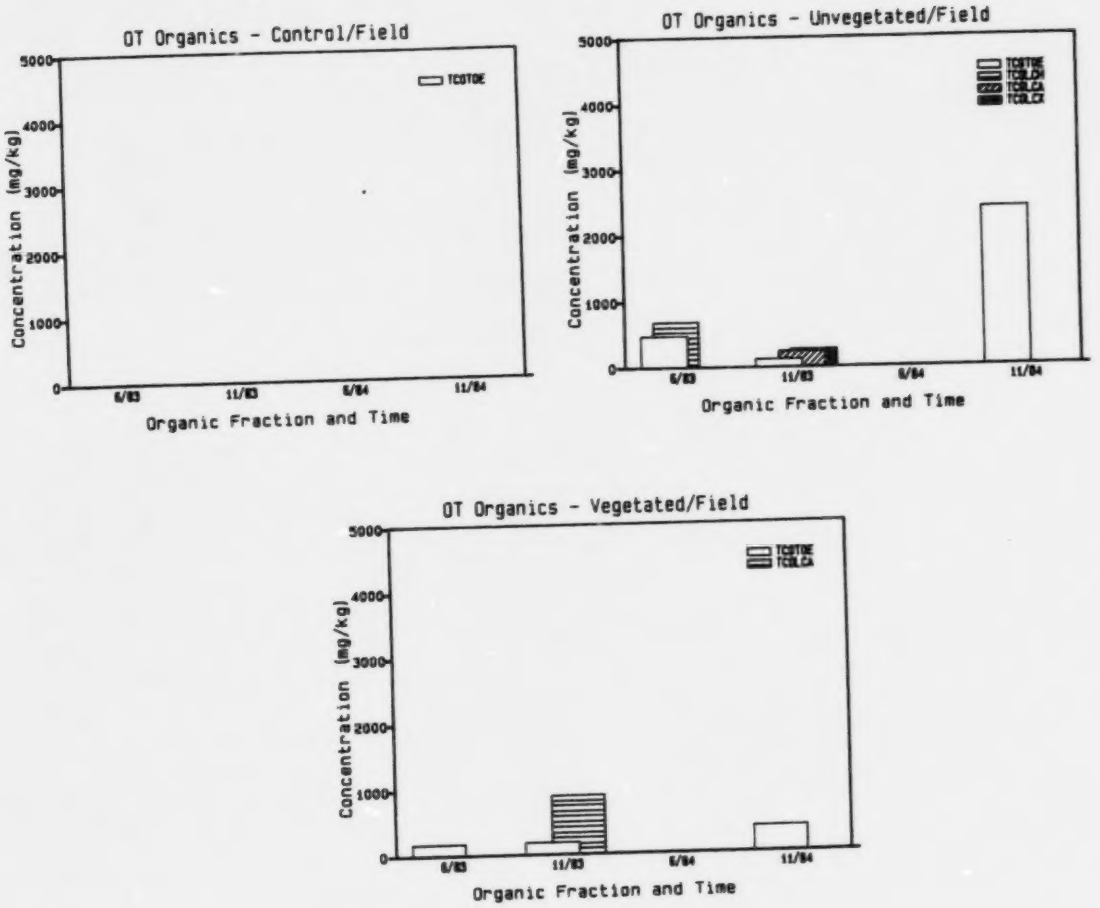

FIGURE 4-8. PLOTS OF TCO FRACTIONS FOR SITE OT/FIELD

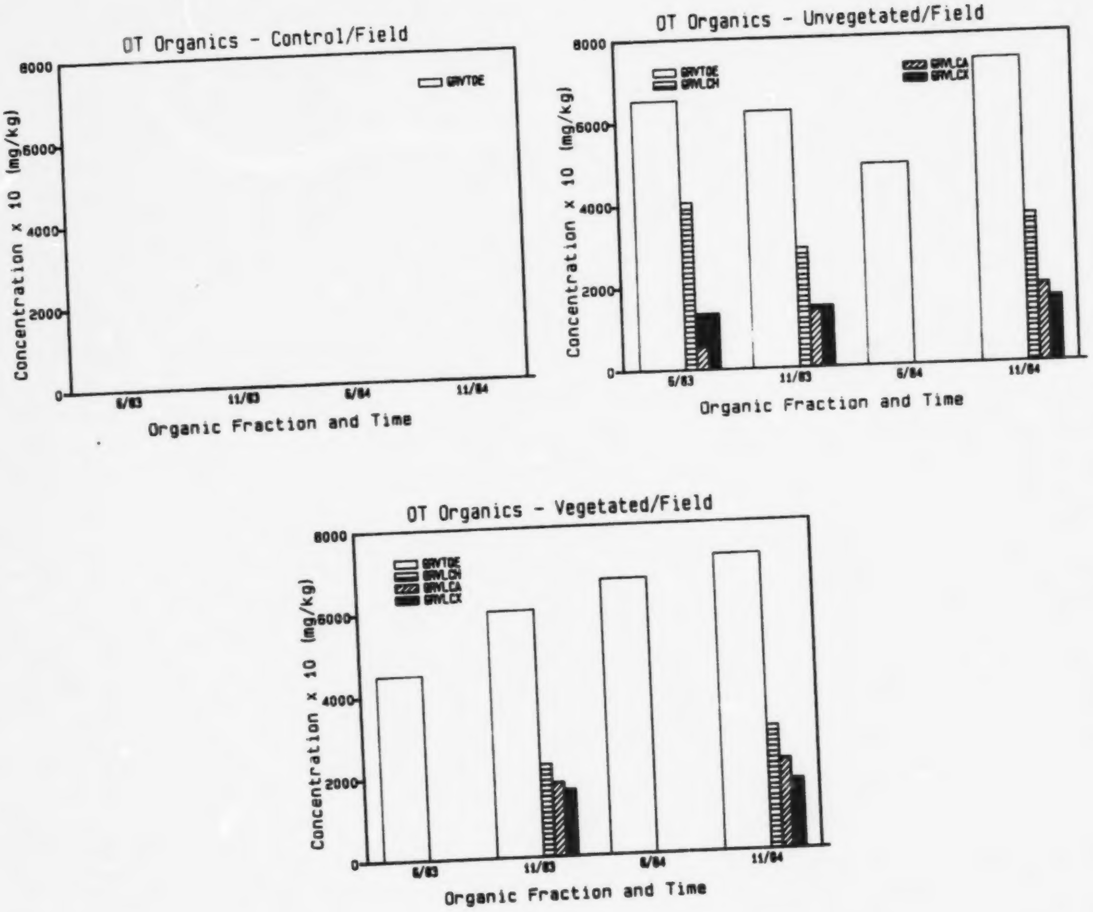

FIGURE 4-9. PLOTS OF GRV FRACTIONS FOR SITE OT/FIELD

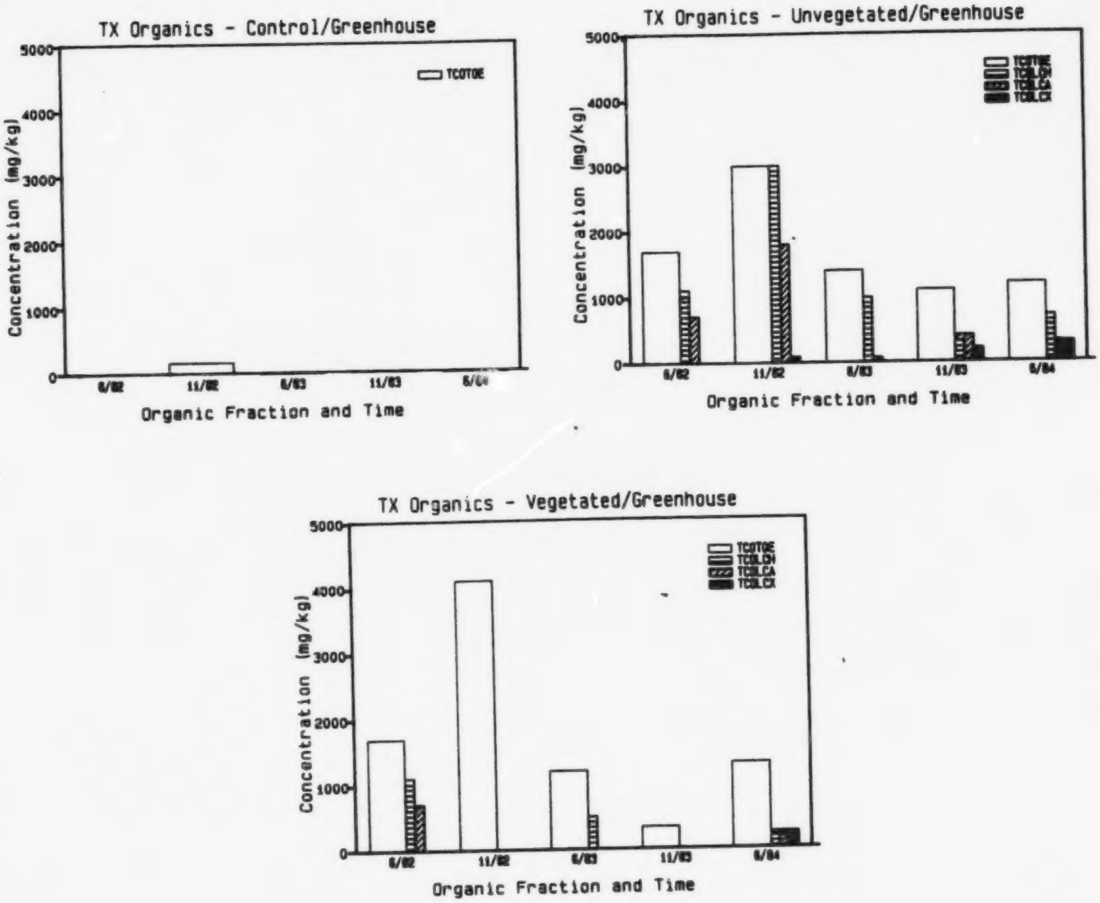

FIGURE 4-10. PLOTS OF TCO FRACTIONS FOR SITE TX

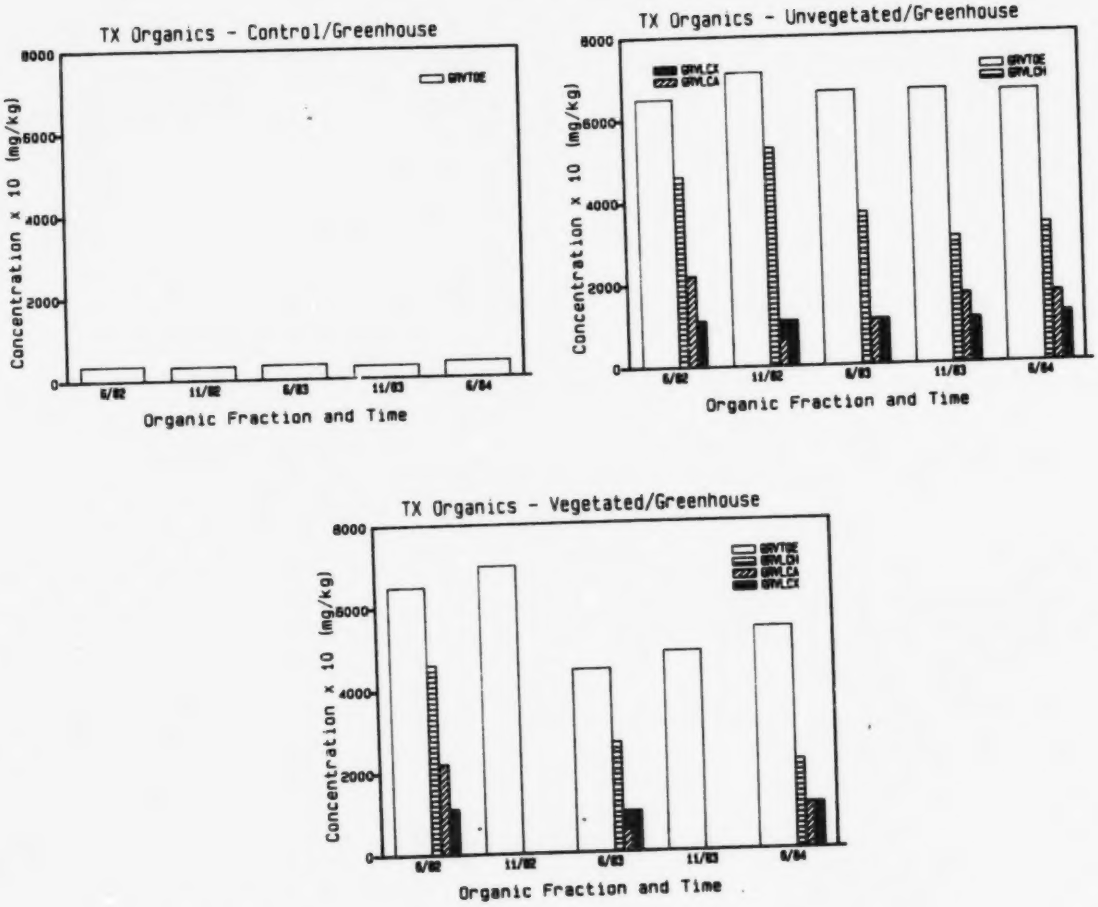

FIGURE 4-11. PLOTS OF GRV FRACTIONS FOR SITE TX

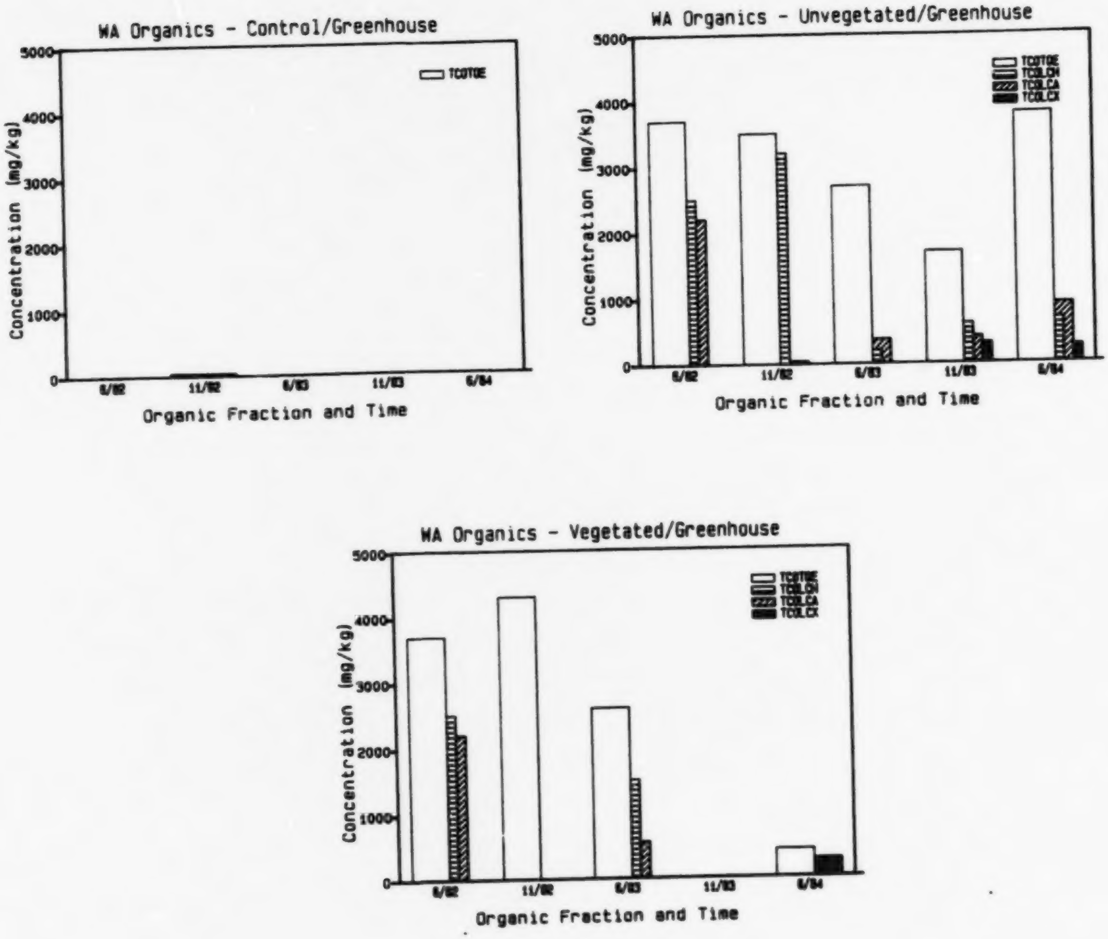

FIGURE 4-12. PLOTS OF TCO FRACTIONS FOR SITE WA

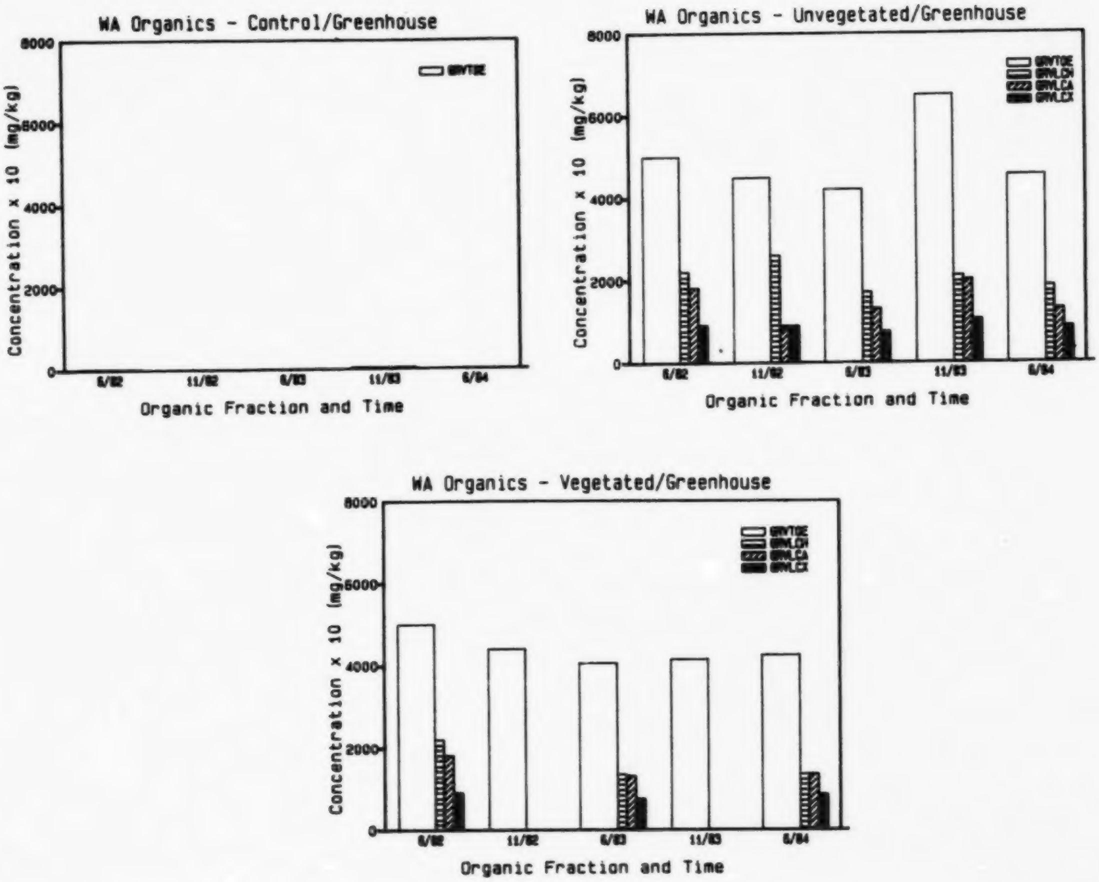

FIGURE 4-13. PLOTS OF GRV FRACTIONS FOR SITE WA

Examination of both vegetated and nonvegetated data, Figures 4-4 to 4-13 indicates a lower percentage loss of the various GRV fractions as compared to the TCO. Aliphatics declined to an average, over the four waste soils, of about 60 percent of the initial value, aromatics to about 75 percent, while polar species decreased hardly at all and even appeared to increase slightly. No common level of the various fractions was reached after 22 months and the waste/soil remained 10 to 20-fold above the respective fractions of a control soil. The polar fraction evidenced slight gains in both low and high boiling groups when separated from the waste/soil mixtures.

The percentage losses for TCO and GRV fractions do not reflect the mass of organic fractions decomposed over the experimental period. For the high boiling group (GRV) the aliphatic and aromatic losses were 3,000 to 20,000 mg/kg soil (6-40 mt/ha) and 3,000 to 10,000 mg/kg soil (6 to 20 mt/ha), respectively. The lower boiling group (TCO) evidenced a greater percentage loss, but on a mass basis was 1,000 to 2,000 mg/kg soil (2 to 4 mt/ha) for aliphatics and the loss 500 to 2,000 mg/kg soil (1 to 4 mt/ha) for aromatics.

BEHAVIOR OF SPECIFIC ORGANICS

This facet of the overall project was undertaken with modest objectives. With three measures of aggregate organics (TOC, O&G, TCO+GRV) and with aliphatic, aromatic, and polar fractions of two boiling point groups, the behavior of organics has already been assessed over the simulated closure period. However, it was concluded that additional desirable objectives would be:

1. to assess the relation of specific organic compounds in the waste/soil mixtures or control soils to the concentrations of these same species in the runoff liquid, and

2. to determine whether losses from the waste/soil mixtures of specific organics can be detected over the two year closure simulation period.

The initial assessment of specific organic compounds identified polynuclear aromatics as present and as a reasonable group to evaluate for this phase of the closure research program.

Polynuclear Aromatics

These compounds were to be determined by chromatography from the single methylene chloride extraction of soils used for TCO, GRV, and the various fractions. In retrospect a more sophisticated isolation procedure is necessary when the PNA is present with large amounts of petroleum residues such as found with refinery landfarms. Thus in comparison to control soils in which there were less organics, the waste/soil extracts required greater dilution. This dilution difference (1:250 or 1:500 versus 1:20) was needed to allow chromatography peaks to be separated or identified relative to the background of the numerous other hydrocarbons. For example, one of the highest PNA values was actually a minor peak relative to the other PNA species, but low compound detector sensitivity and high dilution led to a very high result. Thus comparisons to control soil extracts and among waste/soils have inherent complications for the standard procedure used in this study.

In addition, the chromatography column and procedures were changed midway in the project without adequate verification that results were precisely comparable over the entire project. The November 1983 result had to be selectively rejected since the values were sometimes 100-fold greater than the concentrations reported for dates prior and after. Therefore interpretation of PNA results must include the inherent variability resulting from the analyses as well as from sampling.

The PNA concentrations for WA, TX, OT, and OT-field are summarized in Table 4-3. Of the 10 polynuclear aromatic compounds analysed, three were not detected or were only sporatically above detection limits. These were anthracene, indeno-pyrene, and dibenzofuran. Pyrene was found in four samples at the start of the study. The rest of the PNA species were detected over the span of two years with greater regularity (Table 4-3). Control soil concentrations of PNA were substantially lower than those found in the waste/soil mixtures. None of the control soils (four locations) were uniformly higher in PNA concentrations than the other sites. The range and number of values are given in Table 4-3.

The range of levels for the waste/soils was generally from 0.05 ppm to 5 ppm for those values greater than detection. Examination of trends over the two years revealed no consistent pattern. Generally there was a greater number of less-than-detection-limits results at the last sampling date as compared to the results for August or November 1982. However any further qualitative or quantitative information was not obtainable from these data. It was concluded the determination of loss of PNA was not a practical objective with PNA levels detected for these waste/soil mixtures and with the analytical procedures adopted. That is, tracking of the changes in PNA concentrations in petroleum landfarms exemplified by these sites would require further analytical methods development and may even be limited by sampling variations and the low levels present. The results from the greenhouse were not better than those from the field.

TABLE 4-3. POLYNUCLEAR AROMATIC SUMMARY OF GREENHOUSE POTS AND FIELD PLOTS OVER TWO YEAR CLOSURE SIMULATION PERIOD.

	Polynuclear Aromatic Concentrations, ppm					
	B(a)A	B(b)F	B(k)F	B(a)P + DB(a,j)AC	DB(a,h)A	P
Waste/Soil Mixtures:						
Range of values greater than detection limits	0.04-2.1	0.08-4.7	0.01-0.93	0.16-2.9	0.28-4.0	4-16
Number of values greater than detection limits	12	12	12	11	5	4
Control Soils:						
Range of values greater than detection limits	0.003-0.072	0.002-0.050	0.002-0.006	0.007-0.17	0.037-0.19	0.036-2.6
Number of values greater than detection limits	6	6	5	4	2	3

B(a)A - benz(a)anthracene
B(b)F - benzo(b)fluoranthene
B(k)F - benzo(k)pyrene
B(a)P - benzo(a)pyrene
DB(a,j)AC - dibenz(a,j)acridine
DB(a,h)A - dibenz(a,h)anthracene
P - pyrene

The compounds in Table 4-3 were found routinely over the course of two years and evidenced a qualitative loss. Generally the values at the end of the study were less than detectable or had reached 10 percent to 20 percent of the PNA concentrations at the start of the study. However quantification of the PNA loss was beyond the data validity. The parameters of anthracene, indeno-pyrene and dibenzofuran were essentially less than detection throughout the study.

GAS CHROMATOGRAPHIC/MASS SPECTROMETER (GC/MS) SCAN

Following the use of aggregate organic parameters and the use of specific fractions of those organics (TCO, GRV, LCH, LCA, LCX) the next evaluation of the behavior of waste/soil mixtures during closure was a GC/MS scan. These analyses were qualitative in that the resources available allowed for a single GC/MS scan for each waste/soil in August 82 and another scan in June 84 for the four greenhouse waste/soils and November 84 for the field plot. The reconstructed ion chromatograms (RIC) for the waste/soil of the OT site are given in Figure 4-14. In addition, the OT field RIC is also a part of Figure 4-14. The remainder of the RIC's and mass spectra are given in Appendix C. For each waste/soil or control soil sample, a percentage of the total mass spectrum intensity for all ions which were found in the six incremental regions representing related chemicals was calculated, Table 4-4. Comparisons of each waste/soils system for the August 82 and June 84 sampling events are not positive indications of the absolute change in compound classes over time. Since the absolute magnitude of such peaks and the total mass of organics as determined by this GC/MS procedure are unknown one can only conclude that the diversity of chemical compounds was either reduced or relatively unchanged. These results are not

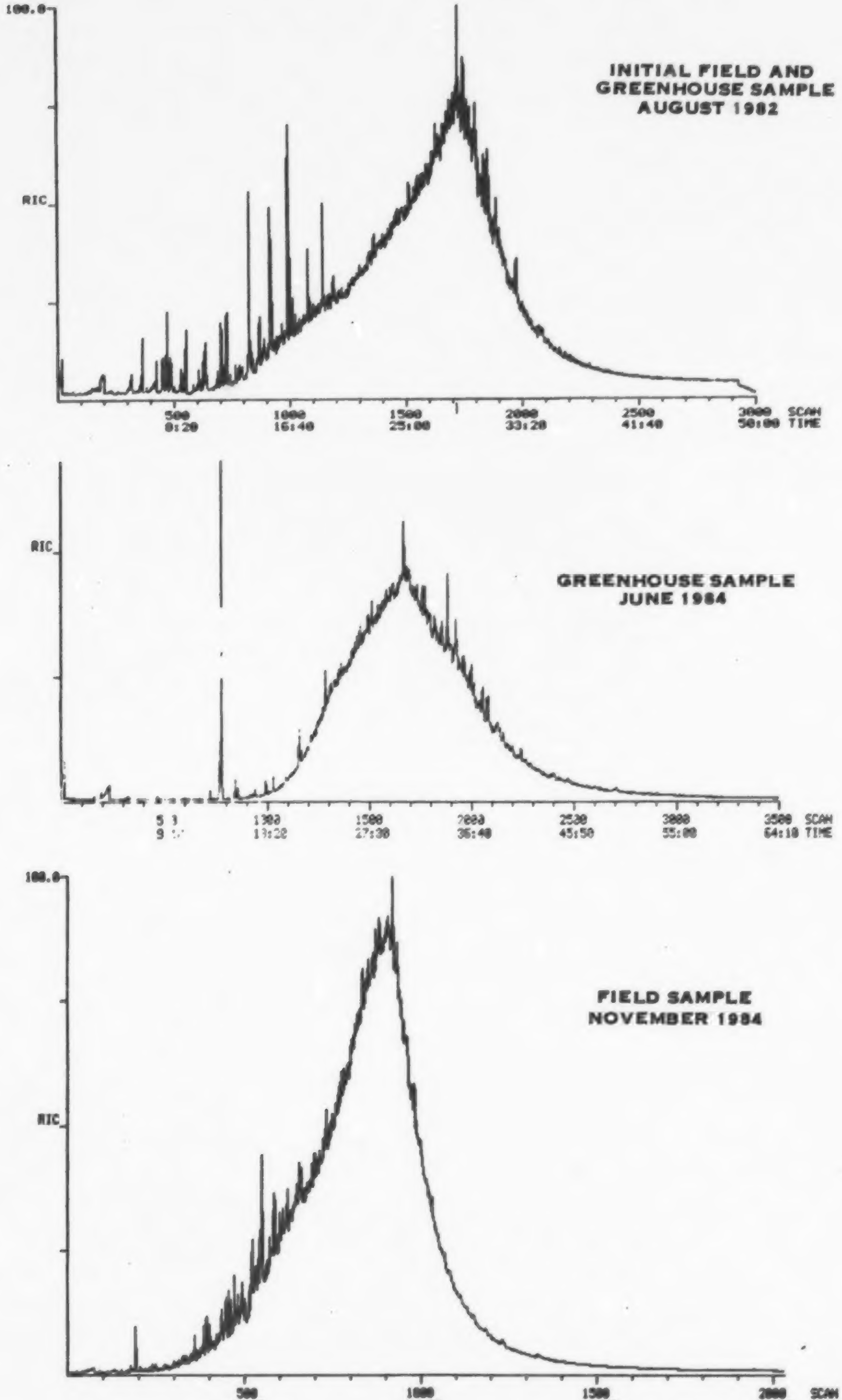

FIGURE 4-14 RECONSTRUCTED GAS CHROMATOGRAMS FOR OT LANDFARM WASTE/SOIL MIXTURE

TABLE 4-4. CHANGES IN GAS CHROMATOGRAPH/MASS SPECTRA OF PETROLEUM LANDFARM SOILS.

Location	Date	Alkyl Naphthalenes	4 Ring PNAs $C_{16}H_{10}$	5 Ring PNAs $C_{20}H_{12}$	6 Ring PNAs $C_{22}H_{12}$	Aliphatic hydrocarbons	Cyclic hydrocarbons	Observations
		(% of total intensity)						
Waste/Soil Mixtures:								
OT	8/82	0.24	ND	ND	ND	1.3	2.4	Substantial peak loss
	6/84	0.23	0.16	ND	ND	0.62	3.1	
OT Field	8/82	0.24	ND	ND	ND	1.3	2.4	Some peak loss
	11/84	0.64	0.24	0.17	0.14	1.3	1.4	
WA	8/82	6.9	5.4	ND	ND	11	11	Substantial peak loss
	6/84	0.65	0.39	ND	ND	1.1	1.7	
TX	8/82	0.26	ND	0.17	0.43	1.6	1.2	Peak changes unclear
	6/84	0.72	0.33	0.11	0.11	1.1	2.2	
OP	8/82	ND	1.2	0.14	ND	1.5	0.96	No discernible peak loss
	6/84	0.27	1.1	2.21	0.69	0.74	1.7	
Control Soils:								
OT, WA, TX (composite)	8/82	ND	ND	ND	ND	ND	ND	
WA	6/84	1.4	ND	ND	ND	0.62	0.15	
TX	6/84	0.69	ND	ND	ND	0.86	1.7	
OT	6/84	0.82	ND	ND	ND	0.49	0.82	
OT Field	11/84	0.29	0.29	ND	ND	0.29	0.57	

necessarily in conflict with the organics losses measured with other analyses previously described.

BEHAVIOR OF INORGANICS

During the course of waste application to soils, the level of inorganics, measured as total constituents (very strong extraction from soil), invariably increases. This is true of land treatment of animal manures, municipal sludge and effluents, petroleum sludges and hazardous wastes. The environmental impact depends on the soil transformations that make inorganics unavailable for movement and the total amount or specific levels of inorganics applied.

In comparison to the organics, the initial metals or inorganics levels were more variable among the various landfarms, Figures 4-15 to 4-19 (initial conditions 6/82). The data are presented in Appendix A. Variations were often in the range of 3- to 25-fold for both total and soluble metals.

In addition, comparison of the inorganic concentrations in the soluble form (mild extractant) to those referred to as total metals indicates that the soluble fraction is often a very small percentage of the total metals. As with the TCO fraction of the organics, the soluble inorganics are thus only a small part of the overall behavior of inorganics in the soil.

Over the experiment duration the total metals were analysed in waste/soil mixtures and in the control soils, Figures 4-15 to 4-19. The controls were unchanged over these two years. No differences between waste/soils with or without vegetation were found for total metals. As with organics, the relative level of a constituent in comparison to that in the control soil is an initial measure of the potential for environmental impact. These ratios are expressed in Table 4-2, in which the inorganics are arranged from the greatest to the least differences from the controls. Nearly 40 percent of the inorganics were indistinguishable from the soils not receiving petroleum wastes (ratio up to 1.3). The largest differences were for Cr, Zn, and Cu.

Examination of total metals concentrations over the two years show that no changes occurred. That is, the experiment consistency was such that the expected conservation of total inorganic constituent concentrations was achieved. An exception to this conservation of total inorganic was noted with sodium which decreased with time (see Appendix A). Since no Na increase in subsoil levels was observed (see later section) it is assumed that Na was leached out of the soil profile or that analytical changes had occurred.

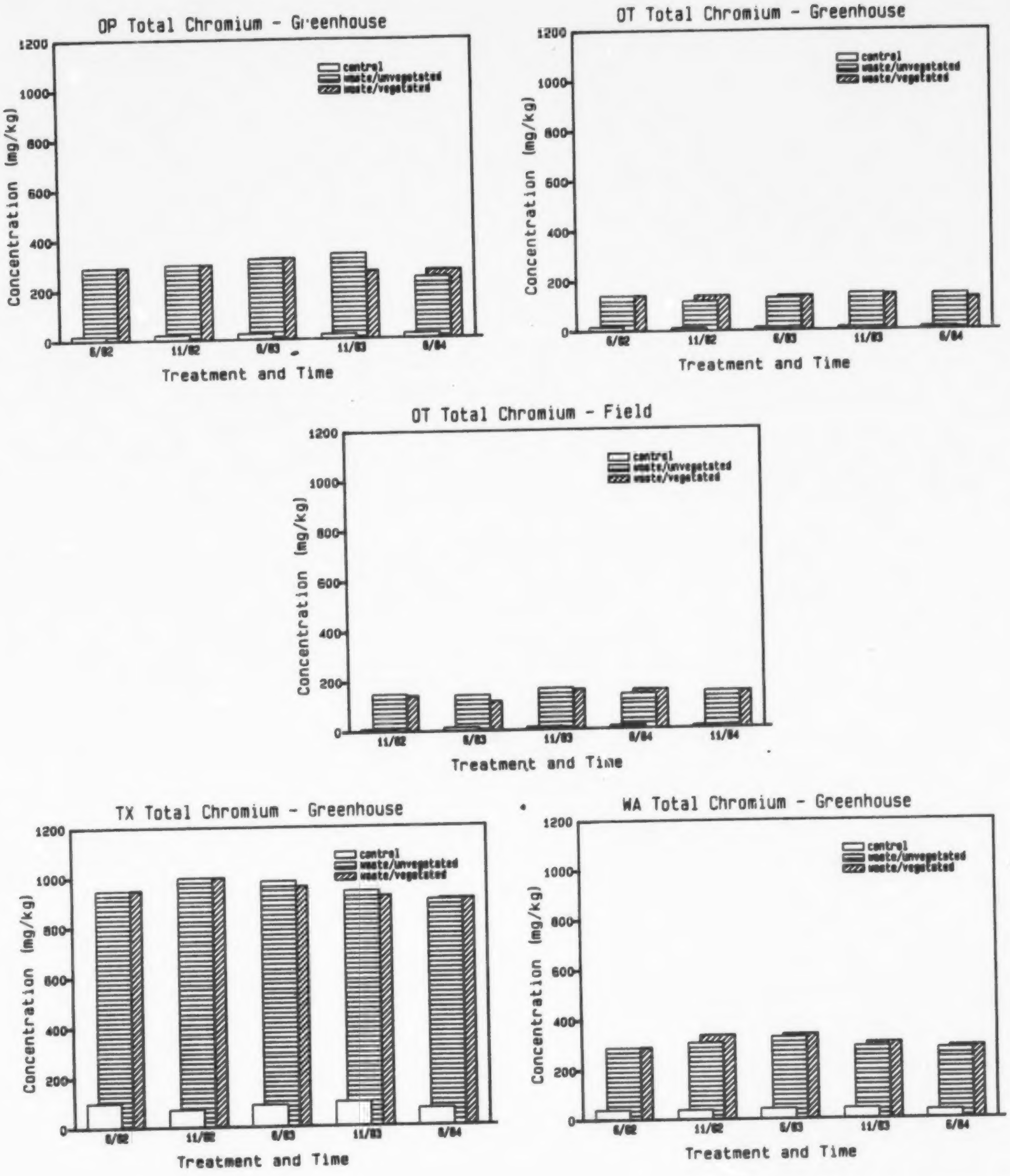

FIGURE 4-15. PLOTS OF TOTAL SOIL/WASTE CHROMIUM CONCENTRATIONS AT ALL SITES

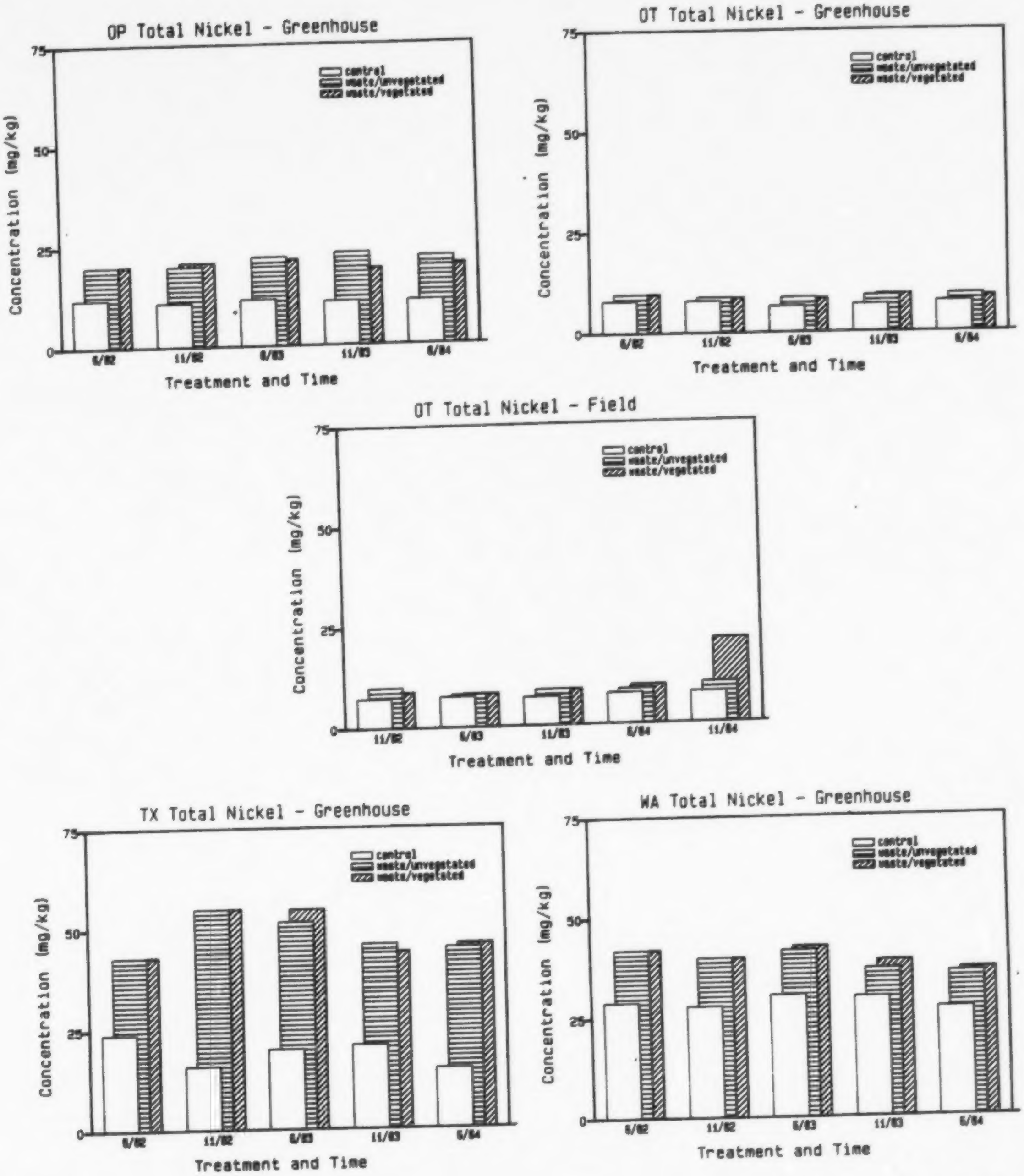

FIGURE 4-16. PLOTS OF TOTAL SOIL/WASTE NICKEL CONCENTRATIONS AT ALL SITES

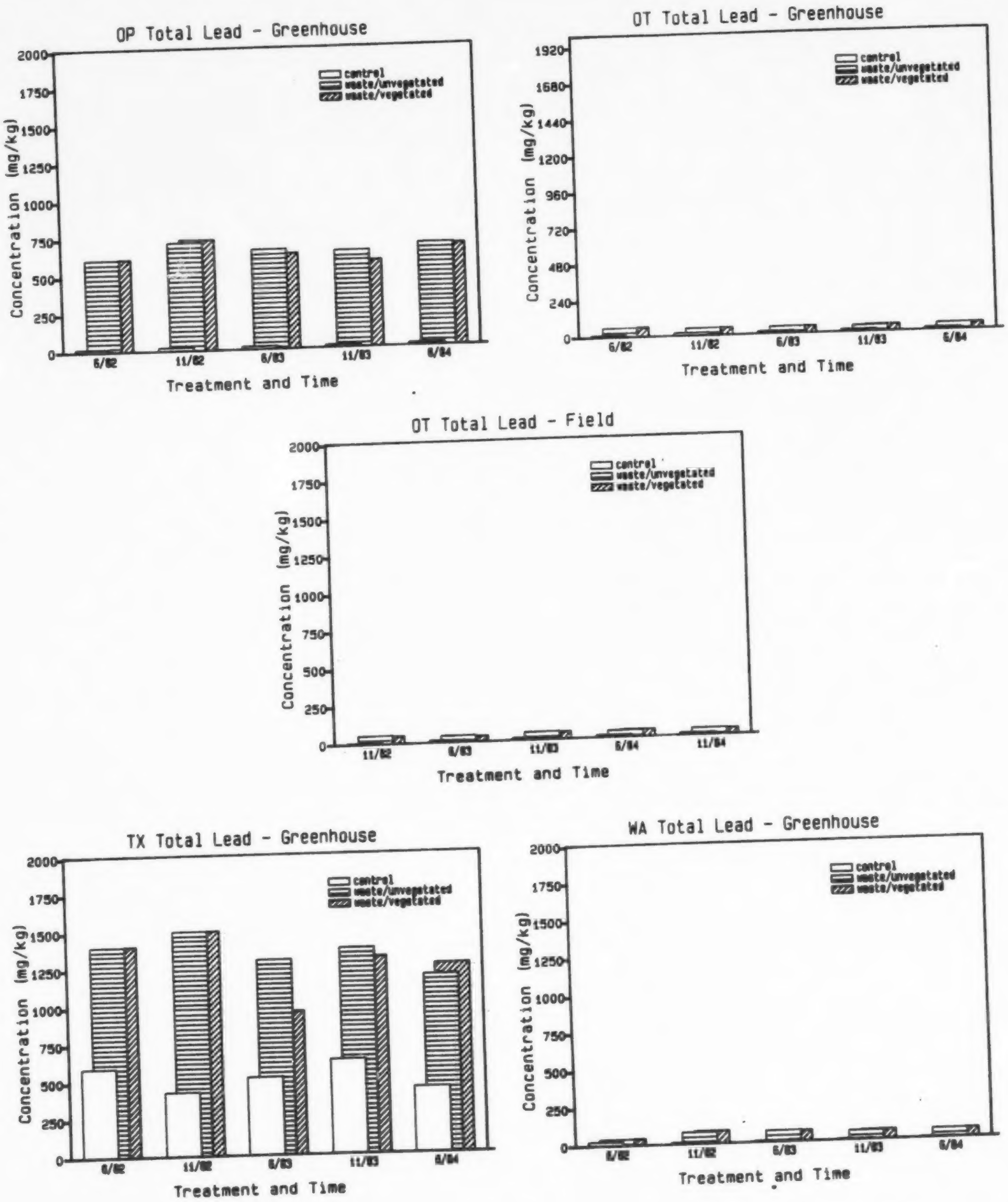

FIGURE 4-17. PLOTS OF TOTAL SOIL/WASTE LEAD CONCENTRATIONS AT ALL SITES

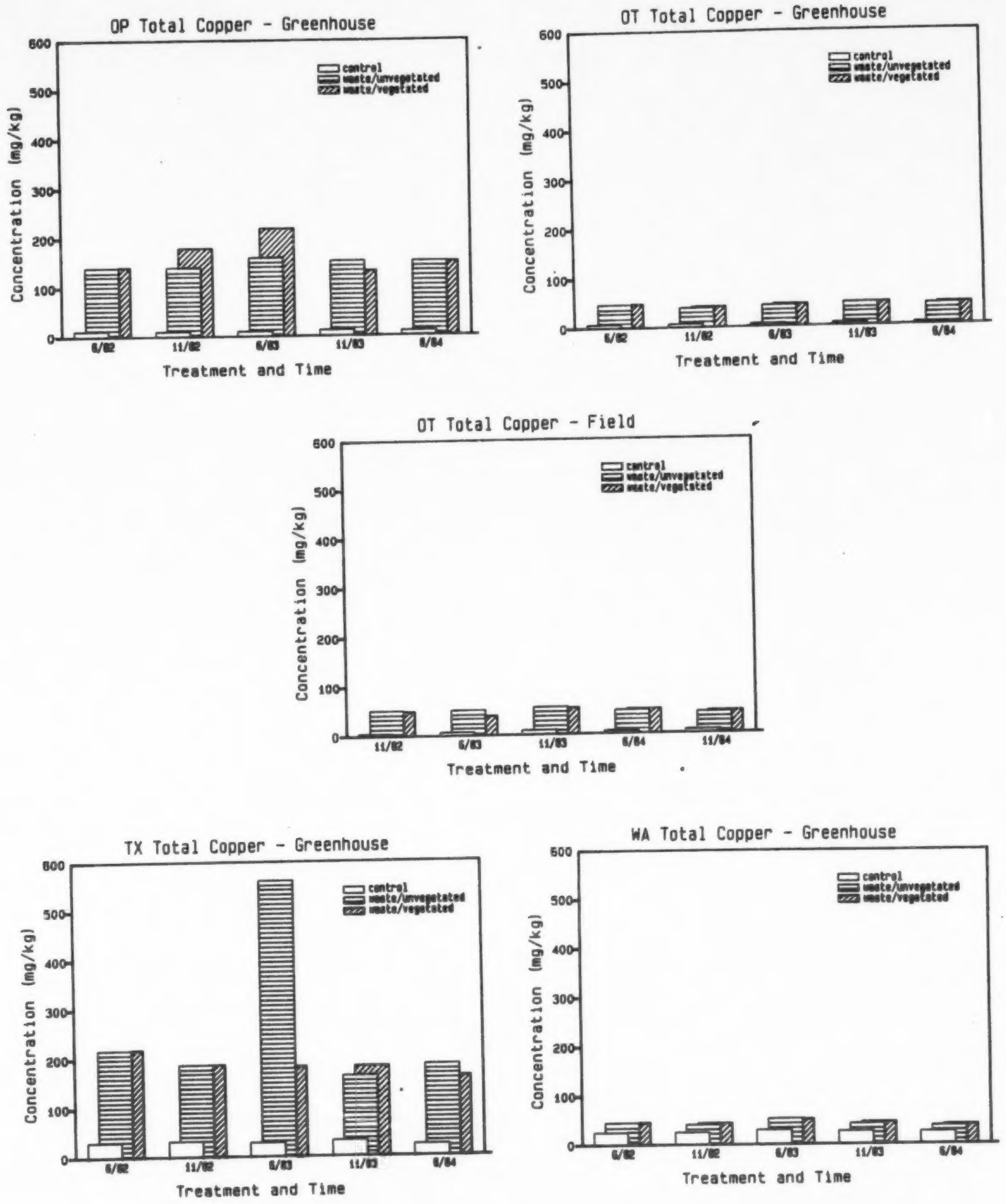

FIGURE 4-18. PLOTS OF TOTAL SOIL/WASTE COPPER CONCENTRATIONS AT ALL SITES

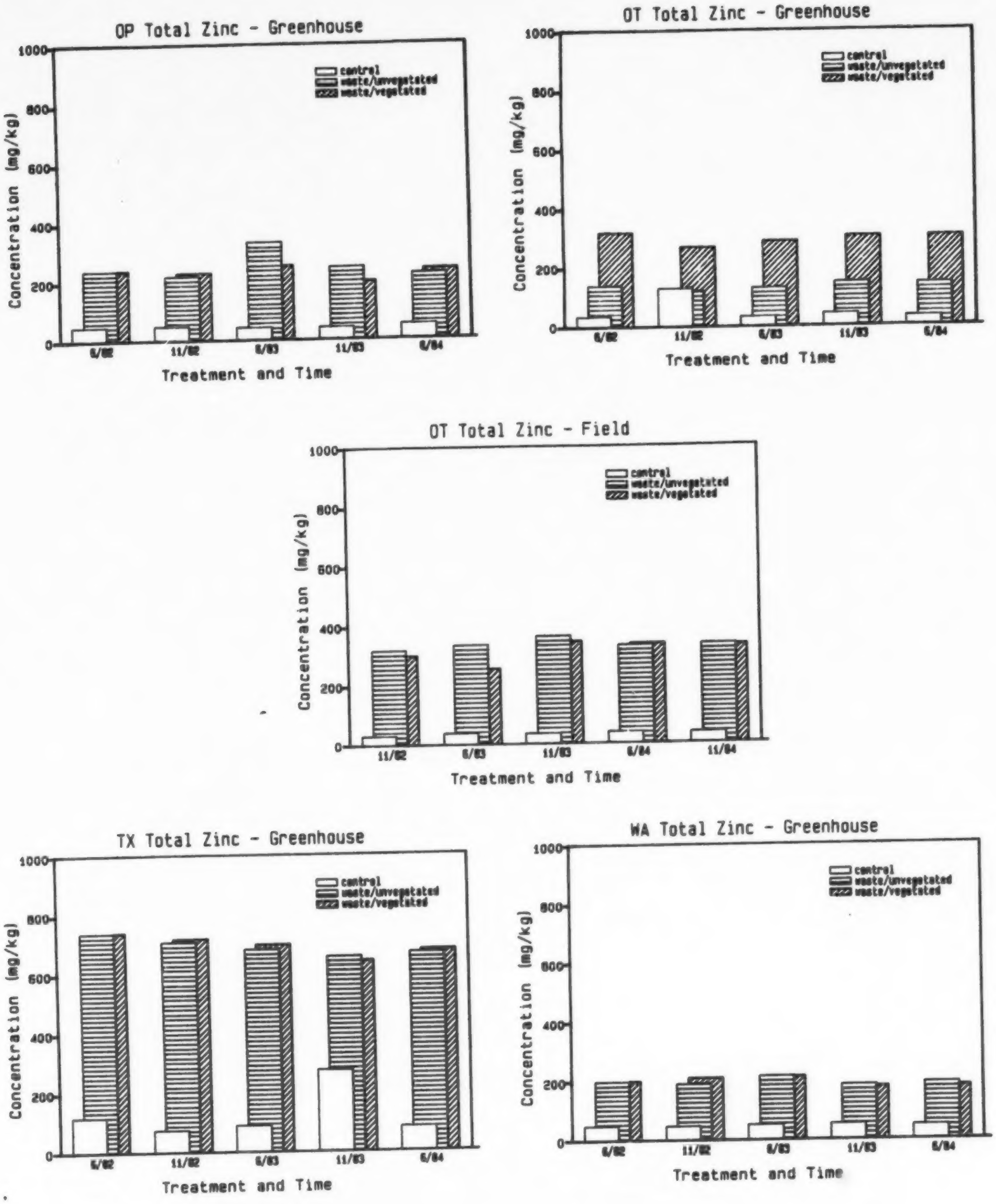

FIGURE 4-19. PLOTS OF TOTAL SOIL/WASTE ZINC CONCENTRATIONS AT ALL SITES

For the mild extraction of inorganics simulating soluble or more readily available forms of constituents the results of the experiment are given in the Appendix A. One should first note that many soluble inorganics were below detection limits and those that were detected were typically a very small percentage of the total constituent levels. Thus differences and changes in the soluble fraction throughout the study are nonetheless a minor fraction of the overall behavior of the inorganics. As with total metals, the control soil soluble inorganics were found to have remained essentially unchanged over the two year experiment.

Those parameters with a high ratio of waste/soil to control with respect to total might be expected to have a high ratio in the soluble form. Such was the case with Zn, Cu, Na, Ca, Sr, and TN. The parameters of soluble Cr and Pb were less than detectable in the control and hence the comparison to the waste/soil mixture could not be made. Two constituents, soluble Mn and Mg, were greater in the waste/soil than the control soil even though the concentrations based on total metals were similar. Three constituents, Al, Fe, and exchangeable phosphorus, were actually greater in soluble form for the control soil in comparison to the waste/soil mixture. This behavior could be related to the relative availability in the soluble extraction procedure of Mn, Mg, Al, Fe, and exchangeable phosphorus in landfarm soils.

The remainder of the inorganic constituents evidenced little elevation of concentrations over those in the control soils for either soluble or total metals. The ratio of soluble concentrations in the waste/soils to the control soils were not as large as those found with certain total inorganic parameters and hence provided less information on possible environmental impact.

Having established the ratio between waste/soil and control soil for inorganic parameters as soluble constituents, the behavior over the two year period was examined. For the majority of the inorganics that were above detection limits, there were no changes over the experiment. That is, large shifts in solubility did not occur even as decreases in organics were achieved. The pH, a critical factor in solubility changes, was essentially constant throughout the study The exceptions to this constancy were Mg, Na, and Ca which appeared to substantially decrease over the two years. No mechanism for these solubility decreases could be determined from the routine sampling and analyses performed in this study.

Another shift was observed in which the vegetated pots were typically slightly lower in soluble inorganic concentrations when compared to nonvegetated pots. This shift was slight, but perceptible. However given that the vegetation was not in massive quantity on the pots throughout the entire study it is unclear why such a shift occurs.

There appear to be few significant changes in total or soluble metals over the two-year simulation of closure. However, it was still necessary to judge the absolute level of those metals which under the Resource Conservation and Recovery Act (RCRA) are designated as parameters of concern. These are referred to as Appendix VIII constituents. The four landfarm waste/soils are a sample of the broader collection of petroleum landfarms nationwide and so evaluations of inorganics are to some extent representative of all such systems.

COMPARISON OF BEHAVIOR OF CONSTITUENTS IN GREENHOUSE WASTE/SOIL MIXTURES WITH FIELD WASTE/SOIL MIXTURES

Only a single landfarm soil was available for a direct comparison of the constituent assimilative phenomena under both field and greenhouse conditions. This was site OT.

Organics

The aggregate organic parameter concentrations in the surface soil zone were presented in Figures 4-1 to 4-3 and Figures 4-10 to 4-13. The control soil in the greenhouse pots and at the field site are essentially the same throughout the two year study for all of the measures of aggregate organics. For the waste/soil mixtures, it was found that the TCO, GRV, TOC, and the fractions of LCH, LCA, and LCX were essentially the same between greenhouse and field experiments (within data variability). Since there were only two dates in which directly comparative data on the fractions (LCH, LCA, LCX) were available, these were not graphically displayed and the reader should consult the data in Appendix A, Table A-18. The similarity of field and greenhouse concentrations continued over the span of two years, thus the mass losses (kg/ha-yr) were similar.

Oil and grease (organics extracted by trichlorotrifluoroethane was consistently higher in soil concentration at the field location when compared to the waste/soil mixture kept in the greenhouse, Figure 4-1. The field levels were 25 to 70 percent greater than the greenhouse pots. If the mass loss is also determined (Table 4-1) this measure of organics decomposition is also slightly higher in the field. The field loss rate for O&G was about 50 percent greater than the greenhouse for the first year and evidenced the same low, variable rate in year two. It is important to note that between field and greenhouse experiments, this O&G difference is small when compared to the concentration differences between waste/soil and control soils.

When reviewing the behavior of vegetated and nonvegetated waste/soil mixtures, no significant differences in the field plots were observed. This lack of a difference is compatible with a similar lack of differences in the greenhouse evaluations of organic parameters. Thus the vegetated and nonvegetated plots were used as checks for the data generated. Overall, the changes in aggregate measures of organic constituents are thus similar between greenhouse pots and field plots, with the exception noted above. This will give credence to the assumption that under closure the behavior of the other greenhouse waste/soil mixtures (TX, WA, OP) would be similar to the respective field sites from which these soils were taken.

Inorganics

It was found that the control soil concentrations under both field and greenhouse regimes were the same and remained constant throughout the study. The total metal concentrations in the soils were essentially the same for vegetated and nonvegetated field plots and also remained constant throughout the two years. The conservation of applied inorganics was thus demonstrated as the same in both greenhouse and the field when using the strong extraction procedure. These data are numerous and hence are only given in Appendix A. The single exception to the similarity between field and greenhouse levels of total metals was sodium. Field levels of Na exceeded those in the greenhouse waste/soil mixtures. Like those in the greenhouse, the field waste/soil Na concentration decreased over the course of this two year study. Again no clear reason for this drop or for the differences in the relative levels between greenhouse and the field could be definitively established.

Using a mild extraction to evaluate the soluble levels of the inorganic constituents it was first determined that the concentrations in the control soils of the field and greenhouse were essentially the same and remained constant over the study. The soluble inorganics in the waste/soils were also the same in the two regimes and over the two year experiment remained unchanged. However it was observed that soluble copper was slightly higher on a reasonably consistent basis in the greenhouse waste/soil mixtures when compared to the field plots. Also the greenhouse waste/soil pH was 0.1 to 0.3 standard units lower than those measured in the field. If this slight shift had any effect on metal solubilization it was not significant enough to be routinely detected over the course of these experiments. As with total metals in the field soils there were no consistent soluble metal differences between plots containing vegetation and those left bare.

In overview of soluble and total inorganics, there was a lack of difference between comparable field and greenhouse conditions. The field differences between waste/soil mixtures versus control soils remained the same as previously described (Table 4-2) for the greenhouse pots. Because of the similarities of behavior between the field and greenhouse, the importance of waste/soil concentrations on surface water runoff concentrations could have been determined either in the field or greenhouse.

ENVIRONMENTAL IMPACTS DURING FIELD CLOSURE

Vertical Migration

Samples were collected at the 25 to 50 cm depth in the field as representative of the first zone to evidence any leaching from the upper waste/soil mixture (see Appendix A). Examination of the total inorganics, soluble inorganics and the aggregate organic parameters revealed no consistent increase at the lower depth over the two-year closure period. The exceptions to this lack of subsurface concentration increase were total copper at both 25 to 50 cm and at 50 to 75 cm and soluble Fe and Al at 25 to 50 cm. The total copper increase was almost identical in timing and concentration at the mid-depth and the deeper zone, approximately 3 to 4 ppm over the two year period. The copper concentration in the surface zone of the waste/soil mixture was about 50 ppm while the subsurface increased from about 3.5 ppm to 7.0 ppm. It could not be determined whether actual Cu migration occurred.

For soluble Al and Fe at 25 to 50 cm there was an increase for both the control soil and the treated plots of approximately the same magnitude. Again an obvious explanation for this behavior is not available. Since the mid and lower-depth data from the greenhouse and field plots were numerous and evidenced no significant variations these results are only presented in the Appendix.

Runoff

During the course of the field experiments five simulated rainfall events were conducted to obtain runoff samples. In these rainfall simulations the precipitation intensity was kept essentially constant. However, the preconditions of the soil (moisture content) were determined by the climatic rainfall pattern and thus could not be controlled. Given this experimental arrangement, the studies were conducted to evaluate

1. the runoff quality from the waste/soil mixture versus the control soil,
2. vegetation effects on runoff quality, and
3. the separation of particulate and solution contributions to the runoff concentrations.

In the phenomena contributing to the transport of chemical constituents from rainfall impinging on the land surface there are two counterbalancing effects which determine the response of an area containing a waste and the corresponding control soil. These are:

1. the relative surface soil concentration of a specific chemical parameter between the landfarm area and the control area;

2. the effect of waste on the infiltration/runoff mechanism relative to the control area without waste.

The higher the ratio of a constituent concentration in the surface soil of a waste treated area to that of the control location, the greater the possibility that the runoff liquid chemical concentration from the waste application plots would exceed that of the control plots. This ratio was previously discussed for the field and greenhouse pots, Table 4-2. Conversely if the waste treatment area had greatly increased organic matter then less runoff and more infiltration would be expected relative to the control soil. This improved infiltration could reduce the erosion of soil and waste particles thus reducing the runoff impact. In fact during the start-up of the rainfall simulator for each event in the field it was observed that runoff occurred rapidly on the unvegetated control plots. Runoff was less rapid from the unvegetated waste/soil plots and the vegetated waste/soil plots. These observations demonstrate the increased infiltration associated with the formation of water-stable aggregates after oily-waste incorporation. The data from this study were examined in light of these counterbalancing mechanisms operative in runoff events. The highest ratios of waste constituent concentration in treated versus control areas were O&G and TCO+GRV, followed by Cr, Zn, and Cu, followed by Na, Ca, Sr, TN, Pb, B and TOC. These different groups were evaluated with respect to the corresponding effect on runoff quality.

The O&G in the runoff for both waste/soil and control plots was usually less than detectable hence no comparison was possible, Appendix A. However for TCO and TCO+GRV the unfiltered concentrations were consistently higher from the unvegetated waste/soil plots compared to the unvegetated control plots, Figure 4-20. While the waste/soil ratios were 300 to 600-fold higher, the runoff liquid concentration of the waste plots was only 2 to 4-fold greater than that of the control plots. From this information one can obtain the relative magnitude of the effect on rainfall runoff as derived from changes in the natural soil surface due to petroleum waste application.

For the group of constituents with the second highest ratio of waste/soil concentration to control concentration, Cu, Zn and

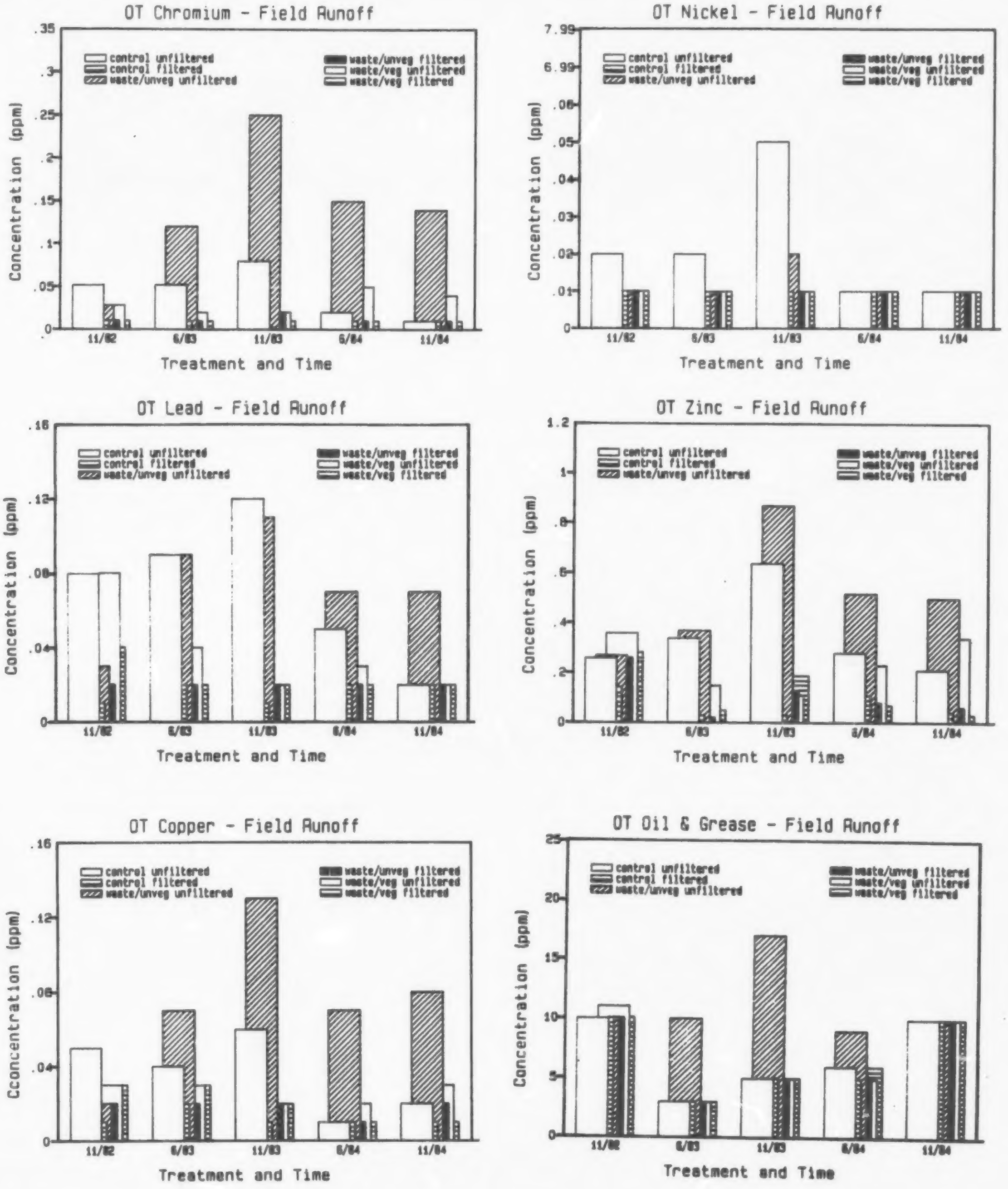

FIGURE 4-20. PLOTS OF TOTAL METALS AND OIL AND GREASE IN RUNOFF SAMPLES AT SITE OT/FIELD

Cr evidenced higher runoff liquid concentrations from the unvegetated waste/soil plots as compared to control plots. This occurred for three out of four of the runoff events, Figure 4-20. The magnitude of the runoff liquid concentration ratio from waste/soil versus control was typically 1.5 to 3-fold, with one ratio of 15-fold. The parameter Zn was not routinely elevated in the runoff liquid from waste/soil plots.

In the group of constituents with the third highest ratio of waste/soil concentration to control concentration, only TN during the first year of the experiment evidenced an elevation in runoff liquid concentration from unvegetated waste/soil plots. In this case the runoff TN concentration ratio was 2 to 3-fold higher for the waste plots. The other parameters in this group Na, Ca, Sr, Pb, and TOC were only slightly elevated between runoff liquid concentrations in the waste/soil and control plots.

The constituents of Co, Ni, Mo, Cd, and Hg were routinely less than detection limits in the runoff liquids and so no information on the comparison of waste/soil and control soils was obtained. For Mg, Fe, Mn, Al, V, and Ti the ratio of waste/soil concentration in the surface zone to that of a control soil were low and approaching 1.0. The constituent V was correspondingly not elevated in the runoff liquid concentration from the waste plots in comparison to control plots. Continuing with the counterbalancing phenomena which determine runoff constituent concentrations, the parameters of K, Mg, Fe, Mn, Al, TP, V, Ba, and Ti were actually lower in runoff level from unvegetated waste/soil plots as compared to unvegetated control plots. This was found to be the case even though the ratio of soil concentrations of these parameters in waste/soil plots versus control plots were generally greater than unity. That is, in the unvegetated control plots the factors which contribute to infiltration and erosion control were less effective than the corresponding plots containing the refinery sludges hence the lower runoff liquid concentrations from the treated area.

In an effort to depict the nonlinear relation between the various waste constituent concentrations in the surface soil and that in the runoff liquid a comparison was made, Figure 4-21. The ratio of waste/soil concentration to control soil concentration was diagrammed versus the same ratio measured in runoff liquid. As can be seen from Figure 4-21, the very high surface zone levels were not reflected in a similar elevation above control for the runoff impact. Note the soil ratio is a logarithmic scale. As the character of the waste/soil surface zone approaches that of the control soil the runoff concentrations also are essentially the same as that from control plots, Figure 4-21. From Figure 4-21 one can conclude that very large ratios of surface soil concentrations of a chemical to that of the control soil are needed to have a major impact on runoff liquid concentrations during landfarm closure.

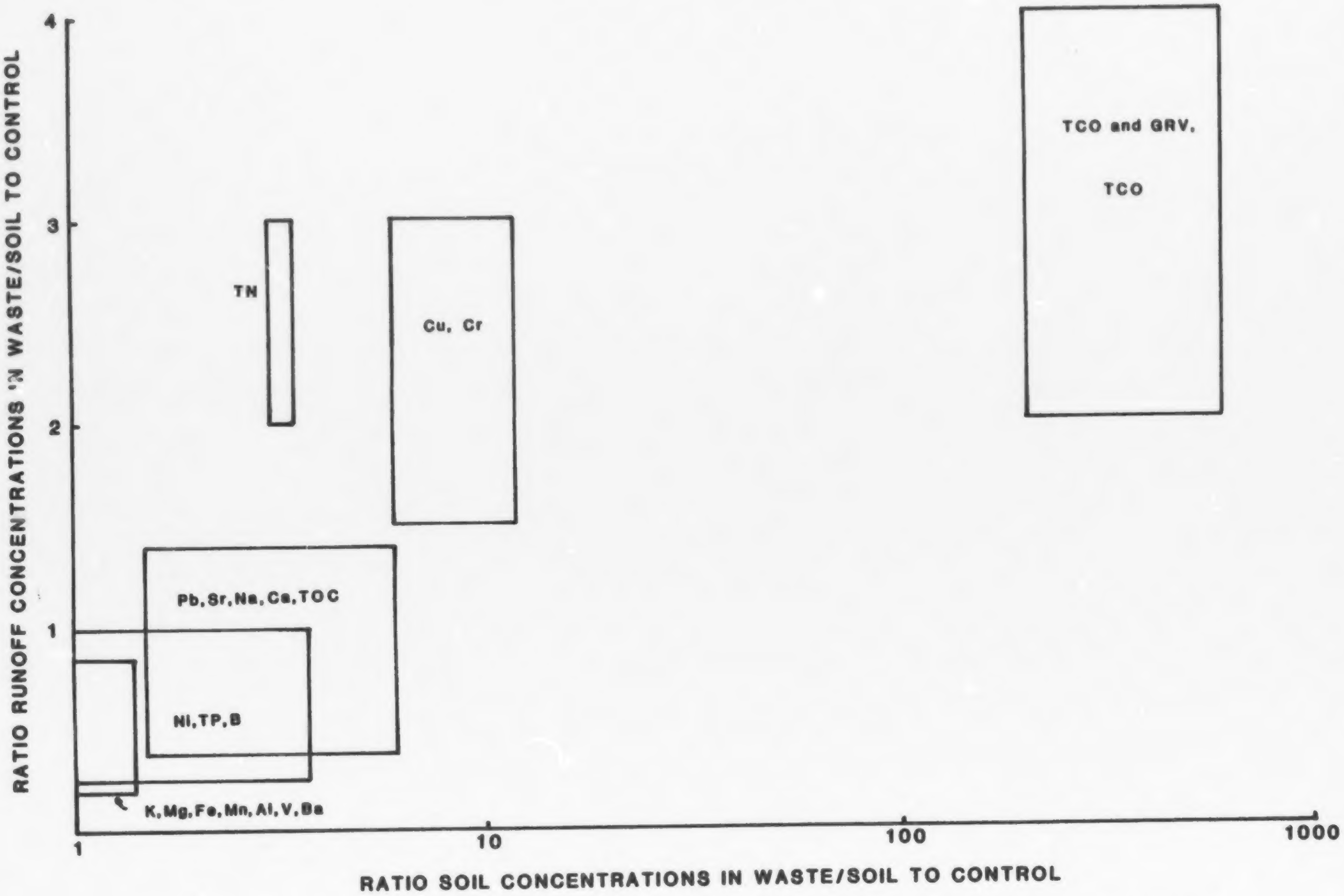

FIGURE 4-21 RELATION OF SURFACE SOIL AND RUNOFF CONCENTRATIONS[41]

Given the level of PNA compounds detected in the greenhouse (OT) and field (OT-field) and the substantial variability it was also possible to assess the relationship of the surface soil concentrations to those in the field runoff liquid. This was an objective for the evaluation of specific organic compounds.

The runoff samples were evaluated for control, vegetated, and unvegetated plots at the start of the study, Table 4-5. Then after one year and two years a single sample was analysed for PNA compounds. Unfortunately the unvegetated sample, November 1984, was lost in the chromatography laboratory and so the vegetated sample was used. However the PNA concentrations for the vegetated and unvegetated samples of 1984 and 1983, respectively, were roughly the same.

For runoff collected from the control plots, November 1982, no PNA species were detected. Since the control soil concentrations were 10 to 100-fold lower than the waste/soil plots it is reasonable that PNA species were not detected. In the waste/soil mixtures each of the eight PNA peaks were found at least once, even though some compounds were less than detectable in the soil. The PNA concentrations in the runoff were very low, in the ppb range.

The runoff liquid concentrations of PNA species from the two waste/soil plots in 1982 were 1 to 10 ppb with only three compounds detected. After the first and second years, the runoff concentrations were even lower, 0.045 to 0.6 ppb, Table 4-5. Expressing the runoff concentration of a particular PNA as a percentage of the median soil level of that species in the runoff plot, the relationship of the surface zone to runoff liquid was determined. The percentages were 0.0003 to 0.002 percent (Table 4-5). The lack of detectable PNA levels from the control plot prevented the type of ratio analysis used previously in this report to evaluate the surface zone and runoff liquid. However as a related comparison, the runoff liquid concentration percentage of the surface zone level was determined for Cr, Zn, Pb, and Cu from these same runoff experiments. These were 0.1 to 0.2 percent from unvegetated plots and 0.02 to 0.06 percent from vegetated plots. For TOC, TCO, and GRV this same percentage for either vegetated or unvegetated was 0.04 to 6 percent. Thus the yield of PNA constituents in the runoff liquid relative to the levels in the surface soil was approximately 10 to 1,000-fold lower than inorganic or aggregate organic parameters measured simultaneously. This could be related to the very low level of PNA parameters.

In November 1984 the runoff liquid from waste/soil and control plots were analyzed by GC/MS. There were no outstanding differences between these measures of organic constituents. The mass spectra and gas chromatograms are given in Appendix C.

TABLE 4-5. POLYNUCLEAR AROMATIC CONCENTRATIONS FROM FIELD SOILS AND RUNOFF LIQUID.

			Polynuclear Aromatic Concentrations,^{1}ppb							
Date of Event	Sample Type	Filtered or Unfiltered	AN	B(a)A	B(b)F	B(k)F	B(a)P + DB(a,j)AC	DB(a,h)A	IP	P
11/82	Control	U	-	-	-	-	-	-	-	-
	Waste/veg.	U	10	-	-	-	-	-	-	-
		F	-	-	-	-	-	-	-	-
	Waste/unveg.	U	-	-	-	-	-	-	-	-
		F	-	1	-	-	-	-	-	3
11/83	Waste/unveg.	U	-	-	0.075	0.45	0.16	0.6	-	-
11/84	Waste/veg.	U	-	0.057	0.8	0.073	0.15	-	0.45	-
Control soil PNA range^2			LDL	4-8	2-5	3-5	7-16	LDL	LDL	LDL
Waste/soil mixture^2										
Range of detectable values			LDL	40-180	180-570	10-660	280-1,200	680-4,000	LDL	LDL
Median of all results			LDL	30	260	120	200	LDL	LDL	LDL
Runoff liquid concentration as percent of median surface zone concentration, 1983-84			-	0.002%	0.00035%	0.0006%	0.0008%	-	-	-

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[1] For PNA abbreviations see Table 4-3, AN - Anthracene, IP - Indenopyrene

[2] Data for Sites OT and OT-field only.

This research experiment also examined the mechanisms involved in the runoff phenomena. A constituent in runoff liquid can be in the solution phase or attached to soil or waste particles. The runoff samples from the field were split and filtered upon collection to yield an unfiltered or total runoff subsample and a filtrate or filtered liquid subsample. The difference in constituent levels in these subsamples is the fraction associated with particles. The comparison of unfiltered and filtered liquid was first made for the control soil plots. The parameters of Fe, Al, Cr, Cu, Zn, Pb and Ti were found to be highly partitioned onto the soil fraction. The filtered liquid concentrations for these metals were of the order of 2 to 10 percent of the total liquid (unfiltered) levels. These chemical constituents are traditionally associated with soil particle composition and are less extractable from soil. For TOC, Na, K, Ca, Mg, Mn, Sr, B, TN, and TP the filtered liquid concentrations from waste/soil plots were between 25 to 100 percent of the total runoff liquid. Thus more of these constituents were associated with the solution phase. The TCO and GRV fractions of organics were about 50 percent partitioned between soil particles and solution phase.

For the runoff liquid from the waste/soil plots appeared to be more readily soluble inorganics than found with natural soils not receiving petroleum wastes. That is, the constituents of Fe, Al, Cu, Zn, Pb, V,and Ti were more typically partitioned 10 to 75 percent in the waste/soil filtered liquid versus 2 to 10 percent for control soil filtered liquid. These more soluble inorganics could have been from the wastes.

Since those constituents more tightly associated with the soil particles demonstrate best the effects of soil erosion, Fe, Al, Cu, Cr, Zn, and Pb were examined to assess the impact of vegetation during closure of waste treatment areas, Figure 4-20 and Appendix A. Comparison was made of the constituent levels in the runoff liquid from vegetated plots to those from unvegetated plots, both having received the same refinery sludge applications. The vegetation appears to lower the runoff concentrations of these soil bound inorganics by 2 to 15-fold when compared to novegetation management. The other parameters (less tightly held in the soil) were essentially the same whether the plot was vegetated or not. These observations are circumstantial information that the vegetation effect is to reduce the chemical concentration in the runoff liquid, primarily by reducing particle erosion. The magnitude of the reduction can not however be precisely established for all parameters.

Vegetation Response

At the end of two growth cycles (1983 and 1984) in both the greenhouse and field the grass was harvested and analyzed for metals levels. These are given in Figure 4-22. Generally the

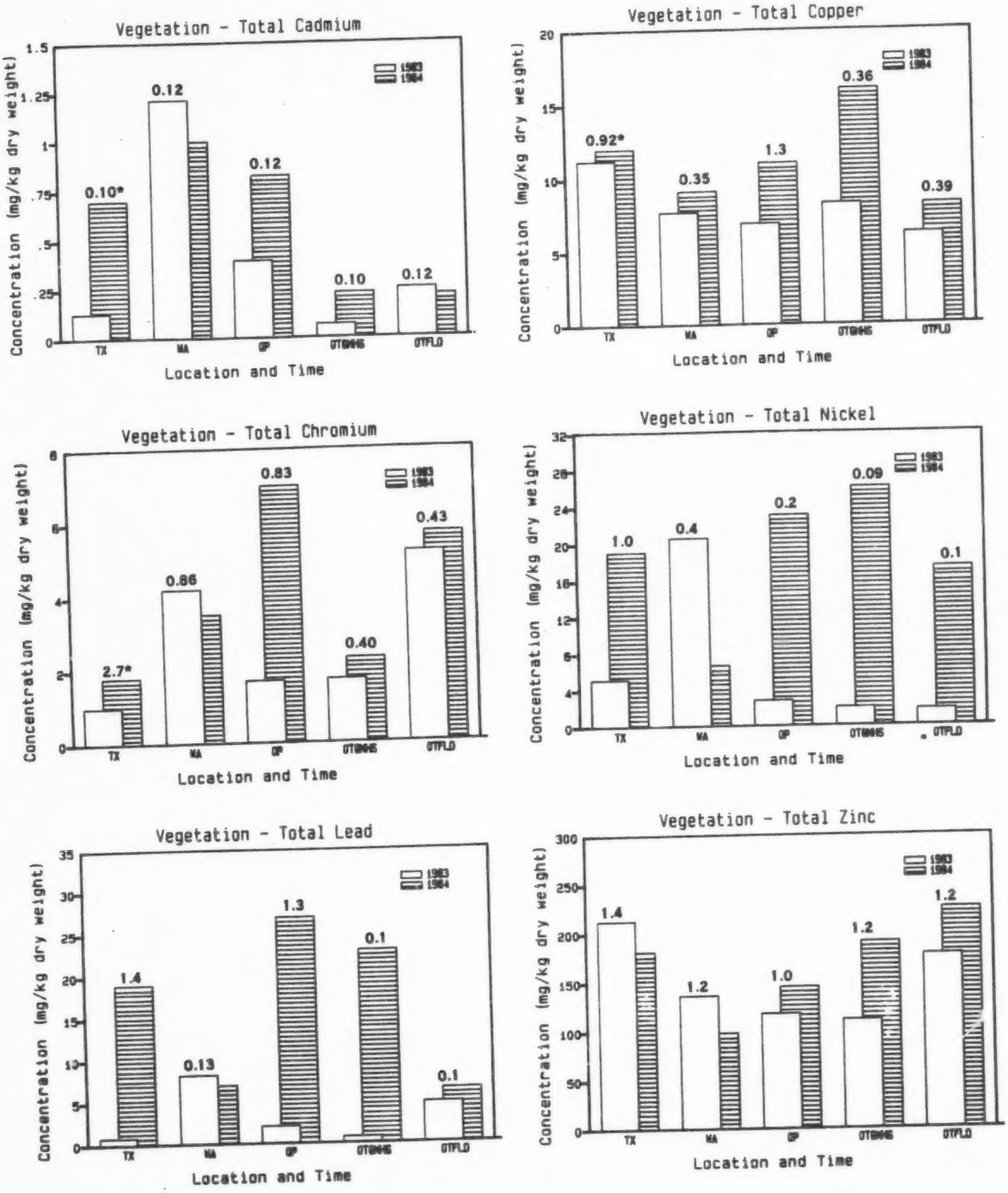

FIGURE 4-22. PLOTS OF TOTAL METALS CONCENTRATIONS IN VEGETATION HARVESTED AT EACH GREENHOUSE AND FIELD SITE. THE (•) INDICATES THE RATIO OF WASTE/SOIL LEVEL TO UPPER ACCUMULATIVE LIMIT ALLOWED FOR MUNICIPAL SLUDGE LAND TREATMENT.

second harvest was higher in metal concentration, but the differences in the vegetation response between the two harvests are assumed to be merely a reflection of the variability of the crops.

It is difficult to assess the impact of the petroleum sludge on the grass from the limited data collected in this project. On the assumption of an increasing crop uptake with higher metals levels in the waste/soil mixture, a quantification of the soil level was included in Figure 4-22. The ratio of waste/soil metal concentration to the accumulative limit used in land treatment regulation and design was calculated for each vegetation harvest. As this ratio remains below unity the direct use as agricultural land is acceptable. In Figure 4-22 one observes:

1. similar soil concentrations with 4 to 5-fold variation in the grass concentration (e.g., Cd),
2. similar grass concentrations with 4 to 5-fold variation in the soil concentration (e.g., Cu).

No consistent trend in crop metal levels was thus discernable for these four landfarm waste/soil mixtures. Examining the relative waste/soil level to the land treatment criteria, chromium in the TX mixture was quite high but actually this site had the lowest chromium vegetation level.

There are few standards of approved metal levels in vegetation which apply unambiguously to sludge land treatment systems. One comparison might be to the metals levels found in long-term municipal sludge land treatment sites with corn production. Values for leaf and stover metal concentrations were obtained, Table 4-6 (after Hinsley and Hansen 1983). The municipal sludge application was that of the intermediate rate. The range of grass concentrations found from the petroleum landfarm mixtures are also reported in Table 4-6. The concentrations of Cd, Cu, and Zn in the grass grown in the waste/soil mixtures appear to be well within the vegetation concentration range of conventional municipal sludge land treatment systems. However, Ni, Cr, and Pb are above comparable municipal sludge vegetation levels. At this stage the vegetation information can only be used to indicate areas for further research or monitoring since no standards are available to judge these results.

Germination Effects

In the closure period the use of a vegetation cover may substantially reduce rainfall-runoff and thus alleviate certain management and operational costs. On an active pertroleum waste land treatment site, there is typically little vegetation due to the active incorporation of material into the upper soil zone.

TABLE 4-6. COMPARISON OF METALS CONCENTRATIONS IN GRASS TO THOSE FOUND IN LONG-TERM MUNICIPAL LAND TREATMENT SYSTEMS[1]

Parameter	Municipal sludge-grown corn Leaf	 Stover	Petroleum land-farm grass
	ppm dry wt.		
Cd	10-30	10-25	0.1-1.2
Cu	9-12	7-8	7-15
Cr	0.5-2	1-2	1-7
Pb	1.5-3	1-6	5-25
Ni	0.6	1-2	2-24
Zn	150-300	200-300	100-200

[1] Corn data from Hinsley and Hansen, 1983.

Thus vegetation must be started on a site shortly after the initiation of the closure period. Such vegetation could conceivably be initiated with a sod overlay in which mature plants would then continue root development. More commonly, grass is established by a seeding process in which germination and then growth would be required.

As a partial evaluation of the germination cycle, a limited experiment was undertaken. The objective was to determine the extent of grass development in two waste/soil materials, as compared to the equivalent soils which had not received petroleum sludge. Three grass species were used. As described in the overall project introduction this germination investigation had limited objectives. However the importance as an initial study was in possibly establishing field-scale requirements or identifying substantial information gaps.

The viability of seeds used in this study was established using a filter paper germination procedure, Table 4-7. Fescue and redtop had similar one to six-day lag periods, but orchardgrass required nearly three weeks to manifest complete germination. The total seed viability was 88, 94 and 98 percent for orchardgrass, redtop, and fescue, respectively. Seed performance in soil under greenhouse conditions can thus be compared to these germination percentages.

When the seeds were planted in the first experiment the measurements taken to determine petroleum sludge effects were average grass height and dry weight on harvest, Table 4-8. The

TABLE 4-7. GERMINATION PERCENTAGES FOR GRASS SEEDS ON MOIST FILTER PAPER.

Time After Initiation	Grass Species		
	Fescue	Orchardgrass	Redtop
Days			
1	0	0	0
3	80	2	78
6	93	39	90
8	94	54	93
22	98	88	94

differences in the texture and fertility of the WA and OP control soils are evident in the control soil grass growth performances. The OP soil had slightly lower 15 and 64 day grass heights as well as 64 day dry weight (except for the redtop dry weight). The latter may simply reflect a difference in the number of plants at maturity between the two control soils.

For the WA waste/soil there was no germination and hence no growth. Observations were that water remained ponded on this soil thus creating very unfavorable growth conditions. The lack of growth could also have been due to large deficiencies of nitrogen. The OP waste/soil trays were closest in fescue grass heights to the control soil. The orchardgrass and redtop were about half the height of the control trays. The dry weight differences simply reflect the lower number of grass plants growing.

In order to establish the germination percentages, a second experiment was conducted. Additionally more mechanical mixing was used to determine whether the ponding was a controlling factor. The two control soils gave essentially the same germination percentages, with orchardgrass still the slowest to germinate, Table 4-9. With the greater mechanical incorporation the seeds in the waste/soil were able to germinate. However the performance was less successful than the OP waste/soil material. The fescue was the most viable of the grass types used.

Another technique that facilitates water mixing to prevent ponding is the use of a surfactant. This technique was tried in a preliminary screening trial. Using fescue seeds, a sorbitol ester surfactant was added to the control soil and to the

TABLE 4-8. GRASS HEIGHT AND DRY WEIGHT AFTER GERMINATION IN WASTE/SOIL MIXTURES AND CONTROL SOILS[1]

	Grass Species		
	Fescue	Orchardgrass	Redtop
Site WA			
waste/soil mixture			
15 day height	0	0	0
64 day height	0	0	0
64 day dry weight	0	0	0
control soil			
15 day height	8.1	2.5	1.3
64 day height	17.3	1.7	10.7
64 day dry weight	4.6	5.7	2.4
Site OP			
waste/soil mixture			
15 day height	6.4	0.5	1.3
64 day height	9.7	5.8	3.0
64 day dry weight	1.2	0.6	0.6
control soil			
15 day height	5.6	0	1.3
64 day height	13.2	12.2	10.7
64 day dry weight	2.0	4.2	4.6

[1] All height measurements in cm, weight measurements in g.

waste/soil mixture. The surfactant was added at concentrations between 0 and 6,000 ppm of soil. Mixing was used as in the previous experiment. The surfactant had no effect on fescue germination in the control soil, Table 4-10. The benefit to seeds in the waste soil mixture was unclear. At a concentration of 2,000 ppm or greater (4 mt/ha) soil wetting was more pronounced while ponding was still evident below that concentration. The germination percentage at 14 days reflects some of that benefit. However, at 30 days the effect relative to no surfactant addition was only evident above 4,000 ppm. Whether at 2,000 or 4,000 ppm the effect is not major and the amount of surfactant required is quite large.

TABLE 4-9. GERMINATION PERCENTAGES FOR GRASS SEEDS IN WASTE/SOIL MIXTURES AND CONTROL SOILS.

	Grass Species		
	Fescue	Orchardgrass	Redtop
Site WA			
waste/soil mixture			
14 days	10	0	4
30 days	66	24	26
control soil			
14 days	56	2	23
30 days	64	14	44
Site OP			
waste/soil mixture			
14 days	43	2	47
30 days	82	38	59
control soil			
14 days	60	6	37
30 days	69	30	44

With respect to the germination study, the following statements can be made.

1. With direct seeding, the WA waste/soil has sufficient oil to preclude effective germination of the three grasses tested.
2. The OP waste/soil had effective grass growth for fescue and partial success with orchardgrass and redtop.
3. Utilizing more mechanical mixing, some germination on the WA waste/soil mixture occurred.
4. Preliminary screening of a surfactant did not greatly improve the germination on the WA waste/soil.
5. Fescue appeared to be the most rapid and viable grass in both germination and growth, and hence a probable candidate vegetation for closure programs.

TABLE 4-10. FESCUE GERMINATION PERCENTAGES USING SURFACTANT IN SITE WA WASTE/SOIL MIXTURE AND CONTROL SOIL.

Concentration of Surfactant (dry soil basis)	Germination: Control Soil 14 days	Germination: Control Soil 30 days	Germination: Waste/Soil 14 days	Germination: Waste/Soil 30 days
ppm	percent			
0	67	67	0	22
10	59	62	0	10
50	57	60	8	13
100	66	66	0	18
250	61	60	0	3
500	60	53	0	7
1,000	60	60	0	5
2,000	58	64	0	16
3,000	62	62	4	14
4,000	55	60	10	37
5,000	58	65	7	25
6,000	57	60	1	28

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TABLE A-1. TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE OP.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd	Cu	Cr
Control, unvegetated, surface													
6/82	77	3000	1500	2100	13000	320	6.2		19000			11.0	19.0
11/82	360	2000	1400	2000	15000	300	5.9		18000		4.60	10.0	21.0
6/83	121	3927	1712	2412	15042	322	6.1	1.6	22850	8.6	<0.30	10.7	22.6
11/83	53	3293	1559	2241	14487	305	6.1	<1.5	20590		<0.30	11.0	19.0
6/84	119	3094	1618	2231	14452	314	6.3	<1.6	20388		<0.24	9.6	19.0
Treatment, unvegetated, surface													
6/82	230	2600	18000	2600	18000	370	7.4		19000			140.0	290.0
11/82	530	2000	5300	2400	19000	360	6.9		20000		0.80	140.0	300.0
6/83	269	3638	6784	2776	21932	371	7.3	3.0	23260	10.9	0.60	160.2	322.4
11/83	188	2796	6679	2665	23897	356	7.5	2.5	20639		0.60	153.0	341.0
6/84	155	2458	5440	2482	19262	356	6.7	2.0	19054		0.45	151.0	243.0
Treatment, vegetated, surface													
6/82	230	2600	18000	2600	18000	370	7.4		19000			140.0	290.0
11/82	560	2300	5400	2500	20000	350	6.9		20000		0.80	180.0	300.0
6/83	218	4253	5178	2777	20202	358	6.9	2.7	24570	9.0	0.61	218.5	323.6
11/83	92	2398	5100	2261	18247	304	6.4	1.7	18600		0.57	132.0	270.0
6/84	145	2567	6119	2675	18497	327	7.3	<1.6	19397		0.47	150.0	272.0
Control, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	330	1600	95	2800	38000	310	12.0		57000		1.10	17.0	15.0
6/83	104	2704	198	3174	44596	323	14.7	2.7	93700	16.1	<0.30	21.0	14.7
11/83	18	2176	81	2759	37630	307	13.0	<2.3	41569		<0.30	18.0	12.0
6/84	85	2290	116	2816	38299	334	13.0	<3.8	49631		<0.22	14.0	11.0
Treatment, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	360	2000	160	2800	37000	340	14.0		50000		1.00	18.0	11.0
6/83	112	2529	317	2832	41967	308	15.8	<2.5	87220	<15.0	<0.30	19.9	10.9
11/83	57	2380	398	2811	39261	313	14.0	3.6	52489		<0.30	20.0	22.0
6/84	49	2224	323	2556	34348	271	12.0	<2.5	40924		<0.23	14.0	11.0
Treatment, vegetated. subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	390	2100	130	2700	36000	270	12.0		37000		1.40	19.0	14.0
6/83	104	2228	488	2325	33005	261	12.7	3.0	66300	19.2	<0.30	17.8	8.4
11/83	97	2537	604	3110	39431	331	16.0	4.6	63699		<0.30	22.0	8.0
6/84	90	2146	586	2623	31626	250	11.0	<2.7	34625		<0.29	15.0	6.7

TABLE A-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE OP.

Date	Ni	Zn	Pb	Sr	V	Ba	B	Ti	As	Sb	Be	Ag	Tl
Control, unvegetated, surface													
6/82	12.0	49.0	<21	17.0	36	120	6.0	490					
11/82	11.0	49.0	25	18.0	36	120	20.0	420					
6/83	11.7	42.1	20	22.0	41	136	23.7	552	41.2	4.5	1.2	<1.0	6.1
11/83	11.0	41.0	17	20.0	37	129	7.9	409	<28.9		1.0		
6/84	11.0	50.0	17	19.0	35	127	23.0	424	<38.1		1.0	<0.8	<15.1
Treatment, unvegetated, surface													
6/82	20.0	240.0	610	91.0	37	210	8.0	440					
11/82	20.0	220.0	720	76.0	34	210	11.0	340					
6/83	22.2	333.4	666	81.6	42	230	17.6	423	47.0	4.8	1.2	<1.0	7.6
11/83	23.0	247.0	646	89.0	38	222	9.0	353	34.5		1.0		
6/84	21.9	223.0	688	71.2	33	187	<1.1	301	<13.5		1.0	<0.9	<4.3
Treatment, vegetated, surface													
6/82	20.0	240.0	610	91.0	37	210	8.0	440					
11/82	21.0	230.0	740	80.0	36	220	12.0	380					
6/83	21.6	253.6	634	80.6	44	249	20.6	518	40.5	3.5	1.2	<1.0	7.2
11/83	19.0	198.0	576	70.0	32	195	7.9	307	28.7		0.9		
6/84	20.0	237.0	681	80.0	34	235	7.9	324	<15.8		1.0	<0.9	<5.0
Control, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	6.5	58.0	29	2.8	68	100	22.0	1100					
6/83	7.5	54.7	15	4.9	73	123	13.7	1279					
11/83	5.7	33.0	16	2.4	70	104	<1.2	1021					
6/84	5.3	39.0	<11	2.5	64	102	1.4	1062					
Treatment, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.5	39.0	26	3.4	70	120	2.0	1200					
6/83	6.1	42.3	17	4.6	78	123	3.4	1395					
11/83	5.4	38.0	26	6.8	79	123	<1.2	1321					
6/84	5.1	33.0	15	4.1	66	108	<1.1	1121					
Treatment, vegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	4.5	40.0	19	2.4	74	120	2.4	1100					
6/83	4.7	30.7	17	5.1	61	104	6.9	1013					
11/83	5.7	41.0	30	8.8	80	139	3.1	1377					
6/84	3.0	25.0	11	7.4	67	115	2.3	1241					

TABLE A-2. TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd	Cu	Cr
Control, unvegetated, surface													
6/82	87	1500	4700	2300	8100	190	3.8		6900			7.1	16.0
11/82	460	1300	4200	2300	8600	180	3.8		7600		1.40	7.3	13.0
6/83	203	2046	4417	2408	8097	192	3.3	<1.0	9661	4.5	<0.30	6.5	12.6
11/83	60	1520	4431	2262	7557	183	3.3	<1.1	7557		0.33	6.3	12.0
6/84	75	1623	4646	2267	8089	189	3.5	<1.0	8263		<0.29	5.4	13.0
Treatment, unvegetated, surface													
6/82	300	2800	19000	2500	8500	170	3.4		11000			47.0	140.0
11/82	500	1500	15000	2200	7700	156	3.1		8600		0.70	40.0	120.0
6/83	339	3416	17829	2593	8080	172	3.3	<1.0	10920	<3.5	0.36	43.2	130.7
11/83	424	3231	20140	2555	7997	152	3.2	<1.1	11199		0.45	47.0	149.0
6/84	213	1900	20075	2399	7791	164	3.0	1.0	8948		0.41	43.0	143.0
Treatment, vegetated, surface													
6/82	300	2800	19000	2500	8500	170	3.4		11000			47.0	140.0
11/82	610	3000	16000	2400	8100	160	3.4		10000		0.70	42.0	140.0
6/83	482	3503	18789	2617	8341	183	3.4	1.2	11710	6.1	0.42	45.1	138.2
11/83	328	2949	19080	2482	7639	146	3.3	<1.1	10429		0.48	48.0	143.0
6/84	284	2780	18555	2473	8008	176	3.4	<1.0	10657		0.33	45.7	128.6
Control, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	300	2100	110	2700	35000	310	13.0		41000		1.10	20.0	10.0
6/83	91	2829	331	3112	44207	327	15.9	<2.7	92440	<15.9	<0.30	21.3	14.2
11/83	95	2319	251	2820	38400	312	14.0	4.0	50780		<0.30	21.0	12.0
6/84	74	2108	174	2593	38951	298	13.6	<3.2	49536		<0.26	15.4	11.0
Treatment, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	310	1500	140	2700	35000	270	13.0		53000		0.90	18.0	8.7
6/83	89	2635	235	2793	38207	289	14.1	<2.5	84400	<14.6	<0.30	21.8	9.9
11/83	36	2543	252	2900	35261	276	13.0	3.4	51330		<0.30	20.0	9.2
6/84	104	2005	295	2666	34830	249	13.0	<3.5	56166		<0.29	19.0	7.5
Treatment, vegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	760	2200	110	2800	34000	270	12.0		41000		0.70	18.0	8.2
6/83	173	2641	384	2878	39237	286	13.6	<2.5	86420	<14.9	<0.30	22.1	10.0
11/83	57	2309	775	2824	36150	308	14.0	4.1	51030		<0.30	19.0	15.0
6/84	90	2051	359	2590	34349	257	13.0	<3.1	49653		<0.29	19.0	8.9

TABLE A-2. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE OT.

Date	Ni	Zn	Pb	Sr	V	Ba	B	Ti	As	Sb	Be	Ag	Tl
Control, unvegetated, surface													
6/82	8.0	35.0	14	14.0	15	65	6.5	240					
11/82	8.0	130.0	19	14.0	15	64	8.0	180					
6/83	6.5	34.0	17	17.4	18	76	30.9	305	17.5	<1.3	0.5	<1.0	4.1
11/83	6.9	42.0	16	16.0	15	132	6.1	202	<11.0		0.4		
6/84	7.6	32.9	17	15.8	16	70	7.6	242	<5.6		0.5	<1.0	2.4
Treatment, unvegetated, surface													
6/82	9.7	320.0	61	60.0	20	140	30.0	400					
11/82	8.9	260.0	52	49.0	17	120	64.0	260					
6/83	8.6	283.3	46	56.6	19	138	25.2	326	18.2	<1.3	0.6	<1.0	3.4
11/83	9.1	315.0	43	66.0	18	162	23.0	289	18.2		0.5		
6/84	9.4	322.0	45	55.0	17	128	40.0	262	9.3		0.6	<0.9	<2.2
Treatment, vegetated, surface													
6/82	9.7	320.0	61	60.0	20	140	30.0	400					
11/82	8.7	270.0	48	54.0	17	140	34.0	290					
6/83	8.4	289.4	46	61.6	20	157	40.9	351	23.8	2.3	0.5	<1.0	4.1
11/83	9.4	304.0	44	58.0	17	149	26.0	266	19.8		0.5		
6/84	8.8	304.2	45	54.1	18	133	34.8	283	<7.6		0.6	<1.0	<2.5
Control, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.4	38.0	20	2.1	68	110	3.2	1100					
6/83	6.3	47.5	14	5.2	79	129	5.7	1522					
11/83	6.2	44.0	27	2.8	71	112	3.9	1141					
6/84	5.2	36.6	16	2.5	73	108	1.3	1230					
Treatment, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.3	39.0	27	2.3	67	120	7.3	1000					
6/83	5.8	34.9	13	3.5	75	129	4.8	1439					
11/83	5.0	33.0	22	3.1	73	128	<1.1	1363					
6/84	5.0	39.6	19	3.3	68	119	3.4	1129					
Treatment, vegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	4.6	36.0	20	2.7	68	120	2.1	1100					
6/83	5.7	35.1	15	3.9	75	131	10.9	1434					
11/83	5.5	52.0	28	5.3	71	128	4.1	1192					
6/84	5.8	31.6	18	3.4	64	119	2.2	879					

TABLE A-3. TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE TX.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd	Cu	Cr
Control, unvegetated, surface													
6/82	160	1800	15000	2900	14000	250	21.0		21000			33.0	100.0
11/82	470	1000	7900	1900	10000	150	16.0		15000		0.60	35.0	72.0
6/83	146	2002	10188	2595	13140	199	15.9	45.5	21290	8.1	<0.30	31.1	88.0
11/83	230	2050	14030	2891	14246	168	17.0	47.0	22189		<0.30	35.0	98.0
6/84	115	864	10386	1735	9552	148	14.0	39.0	9931		<0.21	26.0	69.0
Treatment, unvegetated, surface													
6/82	880	1800	34000	4300	21000	220	28.0		24000			220.0	950.0
11/82	1200	1700	31000	4300	23000	220	32.0		25000		1.10	190.0	1000.0
6/83	981	2634	31986	4515	23781	228	29.7	66.1	29610	16.7	1.09	564.6	983.4
11/83	782	1721	31868	4050	22794	209	26.0	63.0	23718		0.95	166.0	942.0
6/84	778	1849	33140	4059	21255	218	24.0	55.0	24523		0.82	189.0	906.0
Treatment, vegetated, surface													
6/82	880	1800	34000	4300	21000	220	28.0		24000			220.0	950.0
11/82	970	1100	32000	4100	23000	220	25.0		23000		1.20	190.0	1000.0
6/83	671	2853	32646	4546	23771	224	36.7	63.1	30770	19.5	0.97	185.1	963.5
11/83	463	1628	36419	3764	22004	245	38.0	63.0	22688		0.94	185.0	923.0
6/84	581	1934	31270	3781	21653	201	26.0	51.0	25008		0.80	165.0	910.0
Control, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	380	1700	210	2700	39000	320	13.0		58000		1.20	18.0	14.0
6/83	199	2842	274	3138	45956	355	16.1	<2.7	95750	<16.4	<0.30	20.3	17.5
11/83	50	2025	160	2492	35870	302	13.0	<2.7	49590		<0.30	16.0	11.0
6/84	68	2130	220	2747	36482	346	13.0	<2.9	36526		<0.22	13.0	10.0
Treatment, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	450	2000	160	2800	39000	330	13.0		40000		1.60	18.0	14.0
6/83	268	2833	475	2984	44976	338	14.6	<2.6	89750	<15.5	<0.30	19.3	17.6
11/83	149	2134	414	2652	41170	390	14.0	<2.6	47699		<0.30	17.0	14.0
6/84	164	2295	806	2876	34167	301	14.0	<4.5	46549		<0.20	6.1	12.6
Treatment, vegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	380	1600	330	2700	35000	280	14.0		58000		0.90	19.0	10.0
6/83	215	2618	634	2959	39636	252	12.8	<2.4	83520	<14.4	<0.30	21.5	11.9
11/83	147	2311	587	2807	34221	256	14.0	<2.8	50910		<0.30	19.0	8.1
6/84	206	2377	643	2795	35532	256	13.3	<5.8	61362		<0.23	11.3	8.9

TABLE A-3. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE TX.

DATE	Ni	Zn	Pb	Sr	V	Ba	B	Ti	As	Sb	Be	Ag	Tl
Control, unvegetated, surface													
6/82	24.0	120.0	590	47.0	66	140	11.0	140					
11/82	16.0	75.0	430	31.0	45	93	14.0	130					
6/83	20.0	91.4	521	42.0	57	125	12.5	120	41.9	4.1	1.2	<1.0	5.8
11/83	21.0	276.0	631	56.0	61	136	9.2	78	33.6		1.3		
6/84	15.0	82.0	439	35.0	40	95	2.7	13	<8.4		0.9	<0.8	<2.4
Treatment, unvegetated, surface													
6/82	43.0	740.0	1400	120.0	310	130	8.7	160					
11/82	55.0	710.0	1500	120.0	370	370	13.0	170					
6/83	51.7	683.3	1301					240	63.5	5.2	4.5	<1.0	10.0
11/83	46.0	658.0	1372	128.0	347	376	8.3	123	55.7		3.6		
6/84	45.0	671.0	1184	121.0	336	348	8.7	114	30.5		3.7	<1.2	7.6
Treatment, vegetated, surface													
6/82	43.0	740.0	1400	120.0	310	130	8.7	160					
11/82	55.0	720.0	1500	110.0	360	220	14.0	140					
6/83	54.8	700.2	955	135.7	370	103	22.5	229	69.8	6.9	4.3	<1.0	11.3
11/83	44.0	645.0	1314	137.0	345	369	6.3	83	53.3		3.7		
6/84	46.0	681.0	1258	126.7	342	321	35.0	119	31.7		3.7	<1.1	<7.6
Control, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	6.3	51.0	25	2.7	70	110	14.0	1100					
6/83	9.1	52.0	17	4.7	75	125	60.3	1367					
11/83	5.6	37.0	15	2.7	63	98	2.4	950					
6/84	4.1	34.0	14	2.5	64	100	<1.0	1064					
Treatment, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.3	72.0	26	2.0	69	100	2.2	1100					
6/83	7.1	47.4	9					1367					
11/83	6.4	39.0	19	3.6	80	99	<1.2	1036					
6/84	5.5	40.0	16	4.7	61	106	<1.1	1000					
Treatment, vegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.6	43.0	29	3.7	69	110	8.9	1100					
6/83	5.9	34.8	14	6.2	74	128	7.2	1408					
11/83	5.0	32.0	15	5.4	72	121	<1.1	1233					
6/84	5.7	34.9	<16	6.5	70	124	<1.1	1186					

TABLE A-4. TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE WA.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd	Cu	Cr
Control, unvegetated, surface													
6/82	320	810	4900	4800	23000	390	8.8		21000			26.0	41.0
11/82	530	600	4100	4400	21000	330	7.7		19000		1.60	26.0	39.0
6/83	621	1163	6142	5549	23908	390	9.2	1.6	24300	8.0	<0.30	29.5	42.6
11/83	492	1192	6236	5557	24902	426	10.0	<1.5	23189		<0.30	27.0	44.0
6/84	275	670	4196	4477	20807	324	8.3	<1.3	19355		<0.26	25.2	34.0
Treatment, unvegetated, surface													
6/82	650	1600	6900	7100	29000	360	14.0		20000			45.0	290.0
11/82	720	830	6100	6000	28000	320	12.0		16000		1.00	41.0	310.0
6/83	967	2219	8524	7507	30738	377	13.4	3.2	22670	10.9	0.47	53.1	331.3
11/83	645	1700	7008	6868	28690	333	12.0	1.9	19349		0.47	42.0	293.0
6/84	498	1432	6035	6445	27055	318	12.0	<1.9	17481		0.36	37.9	282.0
Treatment, vegetated, surface													
6/82	650	1600	6900	7100	29000	360	14.0		20000			45.0	290.0
11/82	720	840	6200	6500	30000	340	13.0		17000		1.00	44.0	340.0
6/83	1223	3240	9099	8055	32458	381	13.5	2.4	26200	7.9	0.45	52.7	343.0
11/83	539	1704	6488	7033	29960	319	13.0	2.0	19649		0.49	45.0	307.0
6/84	372	1249	5371	6177	27660	291	11.7	1.8	16773		0.38	39.6	293.0
Control, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	320	1800	130	2400	32000	240	12.0		45000		1.00	19.0	7.9
6/83	79	2263	325	2770	38767	259	12.7	2.5	84610	17.1	<0.30	22.7	10.4
11/83	28	1849	280	2555	36960	272	12.0	<2.6	47680		<0.30	20.0	10.5
6/84	65	2121	168	2600	33277	241	12.3	<2.9	45626		<0.26	18.1	8.1
Treatment, unvegetated, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	310	1200	150	2800	40000	340	13.0		50000		1.20	16.0	14.0
6/83	124	3048	194	3287	44716	357	15.1	<2.8	96270	<16.5	<0.30	20.8	16.4
11/83	50	2537	177	2950	35599	347	13.0	<2.1	35100		<0.30	16.0	13.0
6/84	55	2402	203	2780	33339	344	12.8	<2.8	27822		<0.21	5.0	9.1
Treatment, vegetation, subsurface													
6/82	87	3080	83	3353	43146	269	11.7	3.0	81570	19.2	<0.30	17.1	11.7
11/82	350	1400	110	3000	37000	370	14.0		51000		2.50	16.0	12.0
6/83	123	2660	330	3093	45095	356	16.5	<2.5	87390	<15.1	<0.30	17.7	15.2
11/83	39	2373	270	2699	36640	284	14.0	<2.9	52720		<0.30	16.0	12.0
6/84	74	2195	334	2579	34959	327	12.0	<2.7	26699		<0.30	6.0	9.6

TABLE A-4. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), GREENHOUSE STUDY, SITE WA.

Date	Ni	Zn	Pb	Sr	V	Ba	B	Ti	As	Sb	Be	Ag	Tl
Control, unvegetated, surface													
6/82	29.0	50.0	<26	39.0	72	120	2.5	1800					
11/82	28.0	48.0	12	36.0	60	110	4.4	1400					
6/83	30.5	52.6	9	54.4	76	136	5.4	1790	38.7	3.3	0.8	<1.0	5.8
11/83	30.0	53.0	6	56.0	77	138	9.5	1680	<32.6		0.8		
6/84	27.1	48.0	6	34.5	60	113	4.6	1394	<13.1		1.0	<0.9	<5.1
Treatment, unvegetated, surface													
6/82	42.0	200.0	42	330.0	73	330	3.3	1600					
11/82	40.0	190.0	80	370.0	67	330	34.0	1200					
6/83	41.8	216.6	75	442.9	82	408	8.7	1689	45.7	<3.7	0.9	<1.1	6.7
11/83	37.0	185.0	62	410.0	71	368	4.2	1342	30.7		0.8		
6/84	36.0	192.0	61	363.0	62	335	<1.1	1208	<18.2		0.6	<1.2	<6.5
Treatment, vegetated, surface													
6/82	42.0	200.0	42	330.0	73	330	3.3	1600					
11/82	40.0	210.0	84	400.0	68	350	6.0	1100					
6/83	42.7	214.5	73	477.3	89	458	9.9	1759	34.2	<2.5	1.1	<1.1	7.8
11/83	39.0	180.0	63	382.0	70	364	6.1	1336	<27.7		0.8		
6/84	36.8	181.0	61	384.0	62	376	<0.1	1214	<17.6		0.6	<1.2	<6.3
Control, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.2	33.0	14	2.7	67	110	2.3	1000					
6/83	5.9	34.6	18	5.2	78	127	9.8	1484					
11/83	5.8	30.0	18	4.5	81	112	<1.2	1135					
6/84	3.7	25.0	14	2.7	72	115	1.8	1230					
Treatment, unvegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	7.0	46.0	30	4.4	69	100	5.2	1000					
6/83	7.3	51.7	11	5.3	76	126	5.5	1369					
11/83	5.3	37.0	14	6.4	64	104	<1.1	865					
6/84	3.5	35.0	12	6.5	62	95	<1.1	961					
Treatment, vegetated, subsurface													
6/82	6.9	54.4	21	2.6	59	144	7.2	1333					
11/82	5.8	45.0	29	3.6	61	110	15.0	960					
6/83	7.3	54.5	16	9.0	76	116	5.9	1165					
11/83	6.9	47.0	11	34.0	66	101	<1.2	1000					
6/84	4.9	39.0	13	19.0	68	98	<1.3	1009					

TABLE A-5. TOTAL EXTRACTABLE METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, 0-25 cm depth											
11/82	220	1200	3800	2600	8700	220	4.0				0.40
6/83	144	2617	2824	2670	3824	224	3.4	<1.0	10020	4.48	<0.30
11/83	84	1976	2748	2489	8556	216	3.6	<1.1	8836		<0.30
6/84	84	1641	3145	2430	8164	201	3.3	<1.0	7768		<0.27
11/84	78	1544	3185	2367	7563	210	3.4	<1.0	7187		<0.30
Treatment, unvegetated, 0-25 cm depth											
11/82	1100	3000	20000	2600	8200	150	4.0				1.00
6/83	719	4018	20739	2555	7841	166	3.5	<1.1	12050	<3.64	0.50
11/83	539	3325	21576	2535	8494	172	3.6	1.5	11557		0.50
6/84	250	2394	21190	2413	8055	178	3.5	1.2	10159		0.38
11/84	183	2286	21022	2441	8070	161	3.0	<0.9	9381		0.43
Treatment, vegetated, 0-25 cm depth											
11/82	890	2600	16000	2400	7800	130	3.4				0.90
6/83	456	3581	14829	2526	7893	177	3.3	<1.0	11000	<3.54	0.33
11/83	673	3352	18466	2456	7951	137	1.0	1.1	11240		0.40
6/84	286	2515	19648	2485	8337	171	3.2	1.4	10391		1.10
11/84	184	2217	17747	2411	7735	149	3.1	<0.9	8971		0.45
Control, unvegetated, 25-50 cm depth											
11/82	270	1000	1600	2500	7900	150	3.2				<0.30
6/83	141	2146	1841	2703	8011	154	3.0	<1.0	8788	4.7	<0.30
11/83	68	1441	1445	2476	6847	121	2.9	<1.0	6675		<0.30
6/84	117	1992	1876	3037	9197	170	3.5	<1.1	9407		<0.26
11/84	91	1746	1695	2631	7785	145	2.9	<1.0			<0.30
Treatment, unvegetated, 25-50 cm depth											
11/82	330	1000	1100	2600	7100	110	3.2				0.40
6/83	334	2076	1274	2909	7688	120	3.0	<1.0	8586	3.87	<0.30
11/83	146	1666	1222	2754	7670	123	3.3	<1.1	8085		<0.30
6/84	155	1893	1755	3060	8859	178	3.6	<1.0	9239		<0.24
11/84	118	1303	1223	2689	7171	118	2.9	<1.0	6235		<0.29
Treatment, vegetated, 25-50 cm depth											
11/82	310	1100	1500	2900	7800	120	3.1				0.40
6/83	112	1879	1537	3088	7920	128	3.0	<1.0	8118	3.37	<0.30
11/83	125	1603	1552	3075	7706	130	3.3	<1.0	7597		<0.30
6/84	267	1699	1513	2897	7929	155	3.0	<1.1	7975		<0.30
11/84	191	1501	1476	3141	7984	127	2.9	<0.9	7197		0.25

TABLE A-5. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, 50-75 cm depth											
11/82	140	890	1200	2600	7000	110	3.0				<0.30
6/83	108	1745	1544	2990	4119	121	2.6	<1.0	5231	3.37	<0.30
11/83	64	1442	1449	2804	7259	122	2.9	<1.1	7000		<0.30
6/84	104	1640	1988	2576	7942	159	3.0	<1.0	7895		<0.24
11/84	98	1594	1510	2819	7622	137	2.9	<0.9	7662		<0.27
Treatment, unvegetated, 50-75 cm depth											
11/82	290	970	1100	2800	7000	110	3.0				0.30
6/83	286	1708	1251	2920	5296	114	2.6	<1.0	7413	3.76	<0.30
11/83	147	1416	1215	2846	7081	120	3.0	<1.1	6897		0.60
6/84	169	1746	1406	3038	7931	125	2.8	<1.1	8237		<0.26
11/84	84	1230	1197	2748	6788	113	2.4	<0.7	5831		<0.22
Treatment, vegetated, 50-75 cm depth											
11/82	220	1400	1500	3600	8900	140	3.8				<0.30
6/83	167	2110	1528	3171	7703	131	2.8	<1.0	8346	<3.33	<0.30
11/83	109	1573	1438	3059	7415	131	3.0	<1.1	7224		<0.30
6/84	244	1757	1554	3071	7752	128	2.9	<1.1	8016		0.27
11/84	131	1204	1266	2849	6984	119	2.7	<0.8	5822		<0.25

TABLE A-5. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 0-25 cm depth										
11/82	5.4	11.0	7.4	33.0	11	16.0	15	67	6.9	170
6/83	7.2	14.7	7.7	39.7	18	19.3	19	84	15.5	330
11/83	8.9	13.1	7.2	35.6	18	17.3	18	76	8.4	282
6/84	5.9	13.0	7.7	39.0	18	15.0	16	69	5.6	212
11/84	7.1	11.0	7.7	38.0	16	15.0	14	71	11.0	214
Treatment, unvegetated, 0-25 cm depth										
11/82	52.0	150.0	10.0	320.0	56	65.0	17	160	36.0	280
6/83	52.3	143.2	8.3	336.0	45	67.5	18	174	32.6	334
11/83	56.4	165.5	9.0	363.8	53	68.0	20	166	33.1	305
6/84	48.0	138.0	8.6	331.0	45	59.5	19	145	63.0	271
11/84	43.0	147.0	10.0	334.0	44	59.0	17	142	21.0	281
Treatment, vegetated, 0-25 cm depth										
11/82	49.0	140.0	8.9	300.0	50	60.0	16	140	31.0	270
6/83	39.6	118.0	8.4	255.4	38	52.5	18	135	22.6	324
11/83	54.0	159.4	9.0	345.9	49	70.4	19	158	31.1	303
6/84	50.0	156.0	9.7	337.0	50	64.0	19	151	61.0	278
11/84	45.0	148.0	21.0	331.0	43	56.0	16	129	30.0	255
Control, unvegetated, 25-50 cm depth										
11/82	4.7	9.1	7.9	23.0	7	13.0	13	49	4.8	120
6/83	3.8	12.2	7.1	18.5	6	17.9	18	61	16.4	302
11/83	5.4	8.9	6.0	14.8	5	13.4	15	47	6.5	205
6/84	4.7	12.0	8.6	23.0	7	16.0	19	68	7.9	262
11/84	0.6	11.0	12.0	23.0	6	15.0	17	58	7.8	298
Treatment, unvegetated, 25-50 cm depth										
11/82	3.4	8.2	7.0	15.0	3	11.0	12	37	5.2	93
6/83	4.4	11.1	6.9	15.5	5	17.2	17	56	23.4	284
11/83	6.6	11.0	6.4	15.7	14	15.1	18	47	5.3	271
6/84	7.1	13.0	8.2	25.0	7	19.0	19	68	12.0	260
11/84	<1.1	8.6	6.8	18.0	4	13.0	13	44	3.7	148
Treatment, vegetated, 25-50 cm depth										
11/82	4.0	10.0	9.2	18.0	4	12.0	14	41	7.4	160
6/83	4.4	10.6	8.0	16.1	5	16.4	16	52	10.9	211
11/83	5.0	10.3	7.3	17.4	6	15.0	16	48	7.9	209
6/84	6.5	11.0	7.5	21.0	6	17.0	17	55	7.5	234
11/84	<1.0	11.0	6.7	21.0	4	14.0	14	47	13.0	177

TABLE A-5. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 50-75 cm depth										
11/82	3.3	8.0	7.3	16.0	5	10.0	12	36	6.2	120
6/83	2.7	5.0	6.8	14.3	3	15.0	8	47	8.0	119
11/83	8.0	9.7	6.6	15.3	5	14.1	15	45	<1.0	214
6/84	4.2	11.0	7.2	26.0	7	15.0	17	60	14.0	241
11/84	4.0	11.0	7.9	17.0	5	15.0	17	49	19.0	275
Treatment, unvegetated, 50-75 cm depth										
11/82	3.7	8.9	7.4	16.0	3	12.0	13	33	7.7	160
6/83	4.0	7.8	6.8	14.3	5	15.4	11	43	9.8	157
11/83	5.5	10.2	7.4	15.3	6	15.0	16	40	3.4	220
6/84	7.2	11.0	6.9	18.0	6	15.0	17	48	8.2	242
11/84	<0.9	8.2	5.8	20.0	4	13.0	12	37	3.9	151
Treatment, vegetated, 50-75 cm depth										
11/82	5.0	12.0	8.4	21.0	6	15.0	17	44	9.2	180
6/83	4.6	10.6	7.1	14.8	4	17.5	17	50	25.5	271
11/83	4.6	9.9	7.1	15.6	5	15.3	16	43	2.6	219
6/84	4.8	10.0	7.2	18.0	6	15.0	17	48	9.2	228
11/84	<1.0	8.2	6.2	16.0	3	12.7	13	37	4.0	177

TABLE A-6. SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE OP.

DATE	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, surface											
6/82	14.1	58.7	27.4	7.4	7.3	0.65	<0.05	<0.05	14.7	<0.150	<0.02
11/82	9.9	76.7	37.8	10.3	1.3	1.57	<0.05	<0.05	2.6	<0.150	0.02
6/83	14.9	59.7	22.6	6.6	4.2	0.79	<0.05	<0.05	8.2	<0.150	<0.02
11/83	19.3	46.3	29.4	8.0	9.4	0.49	<0.05	<0.05	17.6		<0.02
6/84	35.2	77.1	26.1	11.4	17.6	1.42	<0.05	<0.05	35.6		<0.02
Treatment, unvegetated, surface											
6/82	92.1	24.7	634.5	83.4	<0.5	9.96	<0.05	<0.05	<0.5	<0.150	<0.02
11/82	100.4	30.6	596.5	85.0	0.6	8.86	<0.05	<0.05	0.7	<0.150	<0.02
6/83	100.3	29.0	650.0	89.8	<0.5	9.67	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	100.5	25.8	623.5	86.3	<0.5	8.84	<0.05	0.07	<0.5		0.19
6/84	104.8	33.0	719.0	92.2	4.0	8.96	<0.05	<0.05	8.3		<0.02
Treatment, vegetated, surface											
6/82	92.1	24.7	634.5	83.4	<0.5	9.96	<0.05	<0.05	<0.5	<0.150	<0.02
11/82											
6/83	46.0	18.6	334.5	39.9	<0.5	4.44	<0.50	<0.05	1.0	<0.150	<0.02
11/83	40.2	27.8	537.5	56.0	<0.5	4.91	<0.05	0.06	<0.5		<0.02
6/84	45.5	20.3	279.0	30.9	1.2	0.84	<0.05	<0.05	2.4		<0.02
Control, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	10.3	13.5	3.4	3.4	<0.5	0.89	<0.05	<0.05	<0.5	<0.150	0.06
6/83	7.8	14.5	4.1	4.7	<0.5	0.64	<0.05	<0.05	<0.5	<0.150	<0.15
11/83	6.5	24.7	6.9	7.4	<0.5	1.31	<0.05	<0.05	<0.5		<0.02
6/84	30.1	10.0	<0.5	2.5	<0.5	0.57	<0.05	<0.05	<0.5		<0.02
Treatment, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	14.1	10.2	3.7	3.5	<0.5	0.91	<0.05	<0.05	<0.5	<0.150	0.03
6/83	39.0	20.4	14.9	9.1	<0.5	2.00	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	21.9	14.3	29.5	10.0	<0.5	1.85	<0.05	<0.05	<0.5		<0.02
6/84	62.9	19.5	60.4	19.3	<0.5	3.37	0.06	<0.05	0.6		<0.02
Treatment, vegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	11.2	11.2	3.4	3.1	<0.5	0.86	<0.05	<0.05	<0.5	<0.150	0.04
6/83	51.0	20.4	85.6	29.1	<0.5	5.60	0.10	<0.05	<0.5	<0.150	<0.02
11/83	33.5	22.0	105.1	24.1	<0.5	4.35	0.08	<0.05	<0.5		<0.02
6/84	52.6	8.3	78.9	16.2	<0.5	2.54	<0.05	<0.05	<0.5	<0.150	<0.02

TABLE A-6. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE OP.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
6/82	0.09	<0.05	0.10	0.64	<0.1	0.19	<0.05	0.17	0.21	<0.50
11/82	<0.05	<0.05	0.08	0.37	<0.1	0.28	<0.05	0.27	0.33	<0.50
6/83	0.07	<0.05	0.11	0.21	<0.1	0.14	<0.05	0.14	0.51	<0.50
11/83	0.11	<0.05	0.07	0.55	0.2	0.16	0.07	0.07	0.14	0.72
6/84	<0.05	<0.05	<0.05	<0.05	<0.1	0.19	<0.05	0.26	0.24	0.89
Treatment, unvegetated, surface										
6/82	0.02	<0.05	0.08	0.19	0.2	5.51	<0.05	0.25	0.32	<0.50
11/82	0.31	<0.05	0.07	0.33	<0.1	5.75	<0.05	0.26	0.41	<0.50
6/83	0.26	<0.05	0.06	0.25	<0.1	5.48	<0.05	0.22	0.37	<0.50
11/83	0.28	<0.05	0.08	0.18	<0.1	5.55	<0.05	0.23	1.01	<0.50
6/84	0.39	<0.05	0.13	0.91	0.2	5.74	<0.05	0.35	0.25	<0.50
Treatment, vegetated, surface										
6/82	0.02	<0.05	0.08	0.19	0.2	5.51	<0.05	0.25	0.32	<0.50
11/82										
6/83	0.23	<0.05	0.06	0.14	<0.1	3.24	<0.05	0.22	0.35	<0.50
11/83	0.21	<0.05	0.06	0.15	<0.1	5.15	<0.05	0.29	1.17	<0.50
6/84	0.23	<0.05	0.08	0.70	<0.1	2.42	<0.05	0.25	0.25	<0.50
Control, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	0.05	<0.05	0.24	0.71	<0.1	<0.05	<0.05	0.50	0.21	<0.50
6/83	<0.05	<0.05	<0.05	0.10	<0.1	<0.05	<0.05	0.29	0.16	<0.50
11/83	<0.05	<0.05	<0.05	0.25	<0.1	0.06	<0.05	0.93	1.01	<0.50
6/84	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.35	0.12	<0.50
Treatment, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.16	<0.1	<0.05	<0.05	0.55	<0.19	<0.50
6/83	<0.05	<0.05	<0.05	0.14	<0.1	0.08	<0.05	0.58	0.15	<0.50
11/83	<0.05	<0.05	<0.05	0.22	<0.1	0.23	<0.05	0.33	1.07	<0.50
6/84	<0.05	<0.05	<0.05	0.92	0.2	0.23	<0.05	1.35	0.14	<0.50
Treatment, vegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	0.08	0.47	<0.1	<0.05	<0.05	0.52	0.22	<0.50
6/83	<0.05	<0.05	<0.05	0.21	<0.1	0.24	<0.05	0.20	0.10	<0.50
11/83	<0.05	<0.05	<0.05	0.37	<0.1	0.46	<0.05	0.20	0.84	<0.50
6/84	<0.05	<0.05	<0.05	0.34	<0.1	0.24	<0.05	0.11	0.07	<0.50

TABLE A-7. SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, surface											
6/82	8.5	32.0	96.8	5.0	1.6	0.18	<0.05	<0.05	2.5	<0.150	<0.02
11/82	7.8	22.9	136.0	6.7	1.4	0.16	<0.05	<0.05	2.2	<0.150	<0.02
6/83	7.9	22.7	54.6	2.9	2.4	0.09	<0.05	<0.05	3.9	<0.150	<0.02
11/83	11.1	18.1	67.0	3.2	2.5	0.12	<0.05	<0.05	3.6		<0.02
6/84	8.1	17.3	27.1	5.4	16.9	0.33	<0.05	<0.05	25.1	<0.150	<0.02
Treatment, unvegetated, surface											
6/82	35.2	37.6	240.3	25.7	0.5	0.82	<0.05	<0.05	0.7	<0.150	<0.02
11/82	45.0	28.0	163.9	17.4	0.5	0.35	<0.05	<0.05	0.8	<0.150	<0.02
6/83	23.6	30.3	164.2	17.7	0.6	0.45	<0.05	<0.05	0.7	<0.150	<0.02
11/83	31.4	18.3	170.6	18.4	0.6	0.45	<0.05	<0.05	0.8		<0.02
6/84	18.3	25.7	92.9	12.3	16.3	1.03	<0.05	<0.05	24.4		<0.02
Treatment, vegetated, surface											
6/82	35.2	37.6	240.3	25.7	0.5	0.82	<0.05	<0.05	0.7	<0.150	<0.02
11/82	25.1	26.8	141.1	16.0	0.6	0.35	<0.05	<0.05	0.8	<0.150	<0.02
6/83	18.0	21.7	100.1	10.2	0.5	0.13	<0.05	<0.05	0.7	<0.150	<0.02
11/83	18.1	10.1	119.3	10.6	<0.5	<0.05	<0.05	<0.05	<0.5		0.22
6/84	10.0	14.3	55.7	6.1	7.4	0.36	<0.05	<0.05	11.1		<0.02
Control, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	6.3	12.6	3.1	3.9	<0.5	1.34	0.05	<0.05	<0.5	<0.150	0.06
6/83	15.4	13.0	6.3	3.3	<0.5	0.31	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	7.5	12.1	8.0	2.3	<0.5	0.36	<0.05	<0.05	<0.5		<0.02
6/84	26.7	5.8	<0.5	0.9	<0.5	0.19	<0.05	<0.05	<0.5	<0.150	<0.02
Treatment, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	7.7	9.2	2.6	3.1	<0.5	1.02	<0.05	<0.05	<0.5	<0.150	0.02
6/83	14.6	15.9	6.5	4.5	<0.5	0.84	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	11.1	7.8	6.0	3.7	<0.5	0.51	<0.05	<0.05	<0.5		<0.02
6/84	42.0	9.8	9.4	3.6	<0.5	0.66	<0.05	<0.05	<0.5		<0.02
Treatment, vegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	8.8	10.4	3.2	3.0	<0.5	0.80	<0.05	<0.05	<0.5	<0.150	0.02
6/83	19.1	14.6	19.0	9.1	<0.5	2.33	<0.05	<0.05	<0.1	<0.150	<0.02
11/83	14.5	17.2	41.9	11.9	<0.5	1.30	<0.05	<0.05	<0.5		<0.02
6/84	22.1	9.1	16.1	5.2	<0.5	0.91	<0.05	<0.05	<0.5		<0.02

TABLE A-7. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE OT.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
6/82	<0.05	<0.05	<0.05	0.09	<0.1	0.19	<0.05	0.13	0.07	<0.50
11/82	<0.05	<0.05	0.13	0.42	0.1	0.23	<0.05	0.17	0.32	<0.50
6/83	<0.05	<0.05	<0.05	0.13	<0.1	0.08	<0.05	0.12	0.29	<0.50
11/83	0.07	<0.05	<0.05	0.06	0.1	0.13	<0.05	0.07	0.81	<0.50
6/84	0.13	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.18	<0.05	0.70
Treatment, unvegetated, surface										
6/82	0.24	<0.05	0.07	0.45	<0.1	1.19	0.10	0.31	0.20	<0.50
11/82	0.28	<0.05	0.13	0.42	0.6	0.82	0.08	0.20	0.49	<0.50
6/83	0.30	<0.05	<0.05	0.27	<0.1	0.75	0.07	0.27	0.25	<0.50
11/83	0.30	<0.05	0.12	0.24	<0.1	0.77	0.07	0.02	1.48	<0.50
6/84	0.58	0.27	0.27	1.88	0.2	0.36	<0.05	0.34	<0.05	0.80
Treatment, vegetated, surface										
6/82	0.24	<0.05	0.07	0.45	<0.1	1.19	0.10	0.31	0.20	<0.50
11/82	0.28	0.10	0.07	0.35	<0.1	0.73	0.07	0.43	0.21	<0.50
6/83	0.25	<0.05	<0.05	0.15	<0.1	0.44	0.07	0.13	0.13	<0.50
11/83	0.26	<0.05	0.06	0.15	<0.1	0.57	0.06	0.12	1.08	<0.50
6/84	0.33	0.08	0.07	1.06	0.1	0.23	<0.05	0.15	0.07	<0.50
Control, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.24	<0.1	<0.05	<0.05	0.79	0.14	<0.50
6/83	<0.05	<0.05	<0.05	0.10	<0.1	<0.05	<0.05	0.14	0.19	<0.50
11/83	<0.05	<0.05	<0.05	0.18	<0.1	<0.05	<0.05	0.13	1.53	<0.50
6/84	<0.05	<0.05	0.10	0.71	<0.1	<0.05	<0.05	0.12	0.06	<0.50
Treatment, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.32	<0.1	<0.05	<0.05	0.73	0.11	<0.50
6/83	<0.05	<0.05	<0.05	0.18	<0.1	0.05	<0.05	0.52	0.15	<0.50
11/83	<0.05	<0.05	<0.05	0.13	<0.1	<0.05	<0.05	0.42	0.77	<0.50
6/84	<0.05	<0.05	0.07	0.31	<0.1	<0.05	<0.05	0.36	<0.05	<0.50
Treatment, vegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.20	<0.1	<0.05	<0.05	0.59	0.33	<0.50
6/83	<0.05	<0.05	<0.05	0.57	<0.1	0.05	<0.05	0.35	0.29	<0.50
11/83	<0.05	<0.05	0.05	0.37	<0.1	0.11	<0.05	0.52	0.81	<0.50
6/84	<0.05	<0.05	0.11	0.63	<0.1	<0.05	<0.05	0.15	0.10	<0.50

TABLE A-8. SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE TX.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, surface											
6/82	43.6	16.9	227.2	28.9	<0.5	0.10	<0.05	1.16	<0.5	<0.150	<0.02
11/82	28.1	18.1	264.0	31.6	<0.5	0.20	<0.05	0.87	<0.5	<0.150	<0.02
6/83	36.1	16.7	293.6	34.6	<0.5	<0.05	<0.05	0.98	<0.5	<0.150	<0.02
11/83	40.1	20.2	246.1	31.0	<0.5	0.09	<0.05	1.21	<0.5		<0.02
6/84	50.1	18.7	253.2	27.9	1.8	0.10	<0.05	0.70	3.2	<0.150	<0.02
Treatment, unvegetated, surface											
6/82	479.7	27.4	2777.0	465.6	<0.5	17.75	0.47	0.92	<0.5	<0.150	<0.02
11/82	480.0	16.0	2712.5	520.0	<0.5	18.29	0.31	1.21	<0.5	0.189	0.02
6/83	420.0	19.4	2839.0	504.5	<0.5	18.90	0.33	1.12	<0.5	0.253	<0.02
11/83	460.6	14.6	2938.5	526.9	<0.5	20.77	0.36	1.00	<0.5		0.04
6/84	406.7	16.0	2788.0	475.9	<0.6	18.72	0.35	0.65	<0.5		<0.02
Treatment, vegetated, surface											
6/82	479.7	27.4	2777.0	465.6	<0.5	17.75	0.47	0.92	<0.5	<0.150	<0.02
11/82	593.0	17.7	2998.0	614.0	<0.5	27.20	0.67	0.94	<0.5	0.226	0.04
6/83	218.5	19.6	2949.0	457.1	<0.5	14.88	0.16	1.57	<0.5	0.176	<0.02
11/83	178.1	18.0	3146.0	347.2	<0.5	4.04	0.09	1.91	<0.5		0.05
6/84	186.5	17.2	2794.9	358.4	<0.2	2.38	0.04	0.74	<0.2		<0.01
Control, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	7.3	15.9	6.3	5.3	<0.5	2.10	0.07	<0.05	<0.5	<0.150	0.09
6/83	10.3	11.8	6.4	4.0	<0.5	0.72	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	8.9	13.0	7.6	4.9	<0.5	0.90	<0.05	<0.05	<0.5		<0.02
6/84	34.4	8.3	7.4	3.1	<0.5	0.51	<0.05	<0.05	<0.5		<0.02
Treatment, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	35.3	10.0	8.4	4.0	<0.5	0.95	<0.05	<0.05	<0.5	<0.150	0.03
6/83	144.8	18.2	73.2	32.9	<0.5	3.75	0.10	<0.05	<0.5	<0.150	<0.02
11/83	104.6	20.4	80.7	37.5	<0.5	5.19	0.13	<0.05	<0.5		0.02
6/84	106.6	10.4	111.6	37.5	<0.5	4.32	0.08	<0.05	<0.5		<0.02
Treatment, vegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	82.5	16.6	27.2	15.5	<0.5	3.88	0.09	<0.05	<0.5	<0.150	0.10
6/83	128.2	15.6	149.8	64.0	<0.5	4.38	0.10	<0.05	<0.1	<0.150	<0.02
11/83	113.6	10.9	169.5	67.0	<0.5	3.09	0.11	<0.05	<0.5		0.02
6/84	126.7	7.0	143.1	52.5	<0.1	2.48	0.05	<0.02	<0.2		0.02

TABLE A-8. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE TX.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
6/82	0.14	<0.05	<0.05	0.12	<0.1	1.05	<0.03	0.16	0.14	<0.50
11/82	0.09	<0.05	0.08	0.19	<0.1	1.16	<0.05	0.31	0.24	<0.50
6/83	0.10	<0.05	0.06	0.07	<0.1	1.17	<0.05	0.18	0.19	<0.50
11/83	0.13	<0.05	<0.05	0.05	<0.1	1.04	<0.05	0.15	0.70	<0.50
6/84	0.23	<0.05	0.14	0.61	<0.1	0.96	<0.05	0.21	0.10	<0.50
Treatment, unvegetated, surface										
6/82	0.34	0.09	0.54	6.56	<0.1	10.32	0.30	0.18	0.36	<0.51
11/82	0.29	0.11	0.35	3.28	<0.1	9.46	0.25	0.17	0.38	<0.51
6/83	0.53	0.14	0.44	3.87	<0.1	8.34	0.28	0.13	0.36	0.50
11/83	0.66	0.18	0.46	4.21	<0.1	8.42	0.29	0.13	0.89	<0.50
6/84	0.52	0.14	1.00	5.36	<0.1	7.28	0.19	0.16	0.13	<0.50
Treatment, vegetated, surface										
6/82	0.34	0.09	0.54	6.56	<0.1	10.32	0.30	0.18	0.36	<0.51
11/82	0.45	0.13	0.88	9.08	<0.1	10.73	0.34	0.17	0.39	<0.51
6/83	0.32	0.10	0.23	0.98	<0.1	8.44	0.26	0.13	0.22	<0.50
11/83	0.32	0.09	0.19	1.02	<0.1	8.24	0.33	0.12	0.56	<0.50
6/84	0.40	0.08	0.23	2.07	<0.1	6.90	0.11	0.17	<0.03	<0.06
Control, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	0.07	<0.05	0.14	1.06	<0.1	<0.05	<0.05	1.08	0.13	<0.50
6/83	<0.05	<0.05	<0.05	0.07	<0.1	<0.05	<0.05	0.27	0.18	<0.50
11/83	<0.05	<0.05	<0.05	0.09	<0.1	<0.05	<0.05	0.74	1.16	<0.50
6/84	0.56	<0.05	0.12	0.68	<0.1	<0.05	<0.05	0.33	0.10	<0.50
Treatment, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.58	<0.1	<0.05	<0.05	0.37	0.19	<0.50
6/83	<0.05	<0.05	0.07	0.52	<0.1	0.21	<0.05	0.16	0.15	<0.50
11/83	0.06	<0.05	<0.05	0.54	<0.1	0.19	<0.05	0.38	1.46	<0.50
6/84	<0.05	<0.05	0.17	0.48	<0.1	0.18	<0.05	0.09	0.05	<0.50
Treatment, vegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	0.07	0.50	<0.1	0.11	<0.05	0.47	0.13	<0.50
6/83	<0.05	<0.05	0.07	0.25	<0.1	0.42	<0.05	0.11	0.28	<0.50
11/83	<0.05	<0.05	0.08	0.47	0.5	0.40	<0.05	0.11	1.16	<0.50
6/84	0.03	<0.01	0.06	0.41	<0.1	0.31	<0.07	0.09	0.08	<0.05

TABLE A-9. SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE WA.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, surface											
6/82	21.9	6.5	58.0	17.5	1.4	1.21	<0.05	<0.05	1.6	<0.150	<0.02
11/82	20.6	4.5	67.9	19.9	1.7	1.96	<0.05	<0.05	2.9	<0.150	0.02
6/83	23.3	7.7	41.1	12.9	2.1	0.78	<0.05	<0.05	2.2	<0.150	<0.02
11/83	29.6	11.6	56.9	17.0	3.5	0.68	<0.05	<0.05	3.3		<0.02
6/84	28.0	5.5	26.0	9.7	15.0	0.69	<0.05	<0.05	20.0		<0.02
Treatment, unvegetated, surface											
6/82	130.5	79.3	516.5	194.0	8.0	27.00	0.28	<0.05	53.0	<0.150	<0.02
11/82	129.9	75.0	855.0	259.9	7.9	35.27	0.44	<0.05	62.9	<0.160	0.16
6/83	127.9	74.2	1045.0	285.1	8.7	38.82	0.65	<0.05	61.0	<0.150	0.03
11/83	116.5	69.8	635.5	215.1	6.5	29.95	0.46	<0.05	62.0		0.03
6/84	125.3	75.7	884.5	221.3	9.5	30.33	0.52	<0.05	51.8		0.03
Treatment, vegetated, surface											
6/82	130.5	79.3	516.5	194.0	8.0	27.00	0.28	<0.05	53.0	<0.150	<0.02
11/82	146.5	76.2	817.0	269.4	8.9	36.62	0.43	<0.05	69.9	<0.160	0.14
6/83	76.8	58.9	539.5	161.5	4.9	22.47	0.35	<0.05	42.6	<0.150	0.02
11/83	63.8	52.3	317.2	108.2	4.5	15.59	0.27	<0.05	41.8		0.02
6/84	57.1	56.2	305.2	88.1	1.9	12.38	0.22	<0.50	28.5		0.02
Control, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	13.1	13.2	7.5	5.9	<0.5	1.43	<0.05	<0.05	<0.5	<0.150	0.07
6/83	11.4	11.9	4.9	3.4	<0.5	0.37	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	6.9	8.3	5.3	3.6	<0.5	0.44	<0.05	<0.05	<0.5		0.02
6/84	31.0	5.9	3.4	2.3	<0.5	0.36	<0.05	<0.05	<0.5		<0.02
Treatment, unvegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	19.7	14.3	4.3	4.7	<0.5	1.27	<0.05	<0.05	<0.5	<0.150	0.04
6/83	25.8	15.6	4.6	4.6	<0.5	0.87	<0.05	<0.05	<0.5	<0.150	<0.02
11/83	23.5	20.8	8.5	7.3	<0.5	1.38	<0.05	<0.05	<0.5		<0.02
6/84	36.3	16.2	12.7	8.1	<0.5	2.15	0.06	<0.05	<0.5		<0.02
Treatment, vegetated, subsurface											
6/82	3.1	6.3	1.6	3.4	<0.5	0.98	<0.05	<0.05	<0.5		<0.02
11/82	17.1	13.4	4.6	4.7	<0.5	1.82	0.07	<0.05	<0.5	<0.150	0.12
6/83	39.4	37.5	56.5	38.2	<0.5	11.08	0.28	<0.05	0.7	<0.150	<0.02
11/83	19.1	29.6	38.3	16.6	<0.5	5.00	0.13	<0.05	2.4		<0.02
6/84	74.1	31.0	52.0	24.6	<0.5	7.86	0.19	<0.05	1.0		<0.02

TABLE A-9. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), GREENHOUSE STUDY, SITE WA.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
6/82	<0.05	<0.05	<0.05	0.19	<0.1	0.56	<0.05	0.28	0.09	<0.50
11/82	<0.05	0.07	0.16	0.32	<0.1	0.63	<0.05	0.33	0.29	<0.50
6/83	0.05	<0.05	<0.05	0.22	<0.1	0.33	<0.05	0.25	0.28	<0.50
11/83	<0.05	<0.05	<0.05	0.16	<0.1	0.46	<0.05	0.18	0.74	<0.50
6/84	0.17	<0.05	0.11	0.33	<0.1	0.21	<0.05	0.24	0.13	1.20
Treatment, unvegetated, surface										
6/82	0.16	0.24	0.47	5.06	<0.1	15.95	<0.05	0.51	0.12	<0.50
11/82	0.15	0.21	0.65	7.87	<0.1	21.59	<0.05	0.50	0.16	<0.50
6/83	0.23	0.18	0.78	10.83	<0.1	21.19	<0.05	0.42	0.14	<0.50
11/83	0.18	0.23	0.60	7.73	<0.1	16.66	<0.05	0.54	0.69	<0.50
6/84	0.38	0.16	0.68	13.40	0.1	17.97	<0.05	0.48	<0.05	<0.50
Treatment, vegetated, surface										
6/82	0.16	0.24	0.47	5.06	<0.1	15.95	<0.05	0.51	0.12	<0.50
11/82	0.16	0.25	0.63	8.21	0.8	21.61	<0.05	0.46	0.46	<0.50
6/83	0.15	0.14	0.46	6.47	<0.1	15.87	<0.05	0.56	0.19	<0.50
11/83	0.16	0.19	0.39	4.99	<0.1	19.49	<0.05	0.59	1.48	<0.50
6/84	0.23	0.10	0.42	5.42	<0.1	16.70	<0.05	0.51	0.12	<0.50
Control, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	0.62	0.43	0.2	0.07	<0.05	1.27	0.11	<0.50
6/83	<0.05	<0.05	0.08	0.38	<0.1	<0.05	<0.05	0.25	0.15	<0.50
11/83	<0.05	<0.05	<0.05	0.21	<0.1	0.06	<0.05	0.39	1.44	<0.50
6/84	<0.05	<0.05	0.09	<0.10		<0.05	<0.05	0.33	0.07	<0.50
Treatment, unvegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	<0.05	<0.05	<0.05	0.17	<0.1	0.08	<0.05	0.47	0.16	<0.50
6/83	<0.05	<0.05	<0.05	0.20	<0.1	0.06	<0.05	0.29	0.10	<0.50
11/83	<0.05	<0.05	<0.05	0.19	<0.1	0.14	<0.05	0.36	0.91	<0.50
6/84	<0.05	<0.05	<0.05	0.46	<0.1	0.12	<0.05	0.23	0.08	<0.50
Treatment, vegetated, subsurface										
6/82	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	0.81	<0.05	<0.50
11/82	0.06	<0.05	<0.05	0.52	<0.1	0.07	<0.05	0.60	0.19	<0.50
6/83	<0.05	<0.05	<0.05	0.58	<0.1	0.56	<0.05	0.29	0.07	<0.50
11/83	<0.05	<0.05	<0.05	1.20	<0.1	2.79	<0.05	0.27	0.75	<0.50
6/84	0.07	<0.05	0.12	1.18	<0.1	1.55	<0.05	0.26	0.14	<0.50

TABLE A-10. SOLUBLE SOIL METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, 0-25 cm depth											
11/82	4.9	16.2	60.8	3.1	1.2	0.11	<0.05	<0.05	1.9	<0.15	<0.02
6/83	3.7	3.8	0.5	1.0	<0.5	0.12	<0.05	<0.05	<0.5	<0.15	<0.02
11/83	3.5	26.2	43.5	4.1	6.6	0.13	<0.05	<0.05	10.0		<0.02
6/84	7.0	24.0	18.0	6.0	16.0	0.28	<0.05	<0.05	24.0		<0.02
11/84	11.0	17.0	17.0	5.8	15.0	0.25	<0.05	<0.05	21.0		<0.02
Treatment, unvegetated, 0-25 cm depth											
11/82	93.3	24.2	138.5	24.3	0.9	0.95	<0.05	0.06	1.2	<0.15	<0.02
6/83	0.5	18.8	113.9	15.1	1.0	0.30	<0.05	<0.05	1.5	<0.15	<0.02
11/83	8.1	9.6	79.9	7.9	12.0	0.12	<0.05	<0.05	1.9		0.07
6/84	9.3	11.0	36.0	5.0	4.7	0.17	<0.05	<0.05	7.5		<0.02
11/84	37.0	21.0	104.0	11.0	1.2	0.37	<0.05	<0.05	1.9		<0.02
Treatment, vegetated, 0-25 cm depth											
11/82	100.9	24.5	156.8	24.8	1.0	0.89	<0.05	<0.05	1.3	<0.15	<0.02
6/83	4.9	19.5	83.6	7.5	1.0	0.09	<0.05	<0.05	1.5	<0.15	<0.02
11/83	21.2	12.1	106.7	13.5	1.6	0.35	<0.05	<0.05	2.7		<0.02
6/84	10.0	9.3	26.0	3.6	3.6	0.15	<0.05	<0.05	5.7		<0.02
11/84	31.0	28.0	102.0	9.2	1.7	0.33	<0.05	<0.05	2.6		<0.02
Control, unvegetated, 25-50 cm depth											
11/82	1.5	10.4	26.7	2.9	2.7	0.10	<0.05	<0.05	4.0	<0.15	<0.02
6/83	9.6	41.6	74.2	4.4	2.8	0.23	<0.05	<0.05	4.2	<0.15	<0.02
11/83	7.5	4.9	10.7	5.2	10.4	0.10	<0.05	<0.05	15.3		<0.02
6/84	9.6	13.0	14.0	8.0	19.0	0.25	<0.05	<0.05	29.0		<0.02
11/84	11.0	11.0	10.0	7.8	19.0	0.19	<0.05	<0.05	25.0		<0.02
Treatment, unvegetated, 25-50 cm depth											
11/82	66.0	8.6	8.4	2.7	2.6	0.16	<0.05	<0.05	5.0	<0.15	<0.02
6/83	137.4	10.6	10.3	3.5	3.3	<0.05	<0.05	<0.05	<0.2	<0.15	<0.02
11/83	30.3	14.5	6.4	8.4	20.1	0.16	<0.05	<0.05	30.3		<0.02
6/84	31.0	12.0	21.0	11.0	16.0	0.26	<0.05	<0.05	25.0		<0.02
11/84	43.0	13.0	7.9	9.4	20.0	0.19	<0.05	<0.05	28.0		<0.02
Treatment, vegetated, 25-50 cm depth											
11/82	99.2	9.4	15.2	3.0	1.3	0.09	<0.05	<0.05	2.6	<0.15	<0.02
6/83	7.8	17.9	44.7	13.7	17.7	0.29	<0.05	<0.05	26.9	<0.15	<0.02
11/83	38.0	11.9	22.4	11.0	17.0	0.17	<0.05	<0.05	24.6		0.10
6/84	104.0	27.0	39.0	23.0	42.0	0.80	<0.05	<0.05	66.0		<0.02
11/84	50.0	9.0	8.0	6.8	10.0	0.10	<0.05	<0.05	15.0		<0.02

TABLE A-10. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, 50-75 cm depth											
11/82	9.7	1.0	16.5	2.2	1.5	0.07	<0.05	<0.05	2.6	<0.15	<0.02
6/83	4.2	8.5	27.2	5.8	8.3	0.10	<0.05	<0.05	12.0	<0.15	<0.02
11/83	2.5	7.9	9.7	7.2	15.3	0.17	<0.05	<0.05	22.2		<0.02
6/84	10.0	18.0	14.0	11.0	30.0	0.33	<0.05	<0.05	43.0		<0.02
11/84	11.0	11.0	7.4	8.8	19.0	0.18	<0.05	<0.05	26.0		<0.02
Treatment, unvegetated, 50-75 cm depth											
11/82	54.4	0.5	2.1	1.8	1.8	0.07	<0.05	<0.05	3.0	<0.15	<0.02
6/83	114.5	7.9	4.5	4.4	8.1	0.07	<0.05	<0.05	11.9	<0.15	<0.02
11/83	23.4	11.2	4.8	10.8	22.8	0.17	<0.05	<0.05	33.2		<0.02
6/84	62.0	15.0	25.0	15.0	21.0	0.29	<0.05	<0.05	32.0		<0.02
11/84	22.0	10.0	8.2	8.6	15.0	0.16	<0.05	<0.05	21.0		<0.02
Treatment, vegetated, 50-75 cm depth											
11/82	56.6	10.9	6.0	3.2	5.1	0.08	<0.05	<0.05	7.9	<0.15	<0.02
6/83	6.1	8.9	29.8	8.1	3.1	0.12	<0.05	<0.05	4.4	<0.15	<0.02
11/83	20.8	12.9	12.8	8.3	13.3	0.28	<0.05	<0.05	18.9		<0.02
6/84	88.0	19.0	27.0	17.0	32.0	0.41	<0.05	<0.05	48.0		<0.02
11/84	41.0	10.0	6.0	8.0	14.0	0.13	<0.05	<0.05	20.0		<0.02

TABLE A-10. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Cd	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 0-25 cm depth											
11/82	<0.02	0.07	<0.05	0.08	1.05	<0.1	0.11	<0.05	0.10	0.10	<0.50
6/83	<0.02	<0.05	<0.05	<0.05	0.10	<0.1	<0.05	<0.05	<0.05	0.06	<0.50
11/83	<0.02	0.07	<0.05	<0.05	0.16	<0.1	0.07	<0.05	0.13	0.20	<0.50
6/84	<0.02	0.21	<0.05	0.09	0.27	<0.1	<0.05	<0.05	0.15	0.09	0.54
11/84	<0.02	0.14	<0.05	0.05	0.32	<0.1	<0.05	<0.05	0.11	0.47	0.61
Treatment, unvegetated, 0-25 cm depth											
11/82	<0.02	0.10	<0.05	0.06	0.15	<0.1	0.74	0.08	0.19	0.21	<0.50
6/83	<0.02	0.10	<0.05	0.10	0.52	<0.1	0.57	<0.05	0.18	0.21	<0.50
11/83	0.07	0.25	<0.05	0.15	0.44	<0.1	0.40	0.07	0.11	0.60	<0.50
6/84	<0.02	0.18	0.05	0.07	0.49	<0.1	0.16	<0.05	0.10	0.24	<0.50
11/84	<0.02	0.20	<0.05	<0.05	0.68	<0.1	0.46	<0.05	0.11	0.14	<0.50
Treatment, vegetated, 0-25 cm depth											
11/82	<0.02	0.13	<0.05	0.08	0.22	<0.1	0.87	0.08	0.20	0.18	<0.50
6/83	<0.02	0.23	0.32	0.09	0.29	<0.1	0.42	<0.05	0.09	0.21	<0.50
11/83	<0.02	0.16	<0.05	0.07	0.35	<0.1	0.57	0.06	0.19	0.91	<0.50
6/84	<0.02	0.14	0.05	0.06	0.43	<0.1	0.13	<0.05	0.08	0.19	<0.50
11/84	<0.02	0.36	<0.05	0.10	0.88	<0.1	0.47	<0.05	0.12	0.15	<0.50
Control, unvegetated, 25-50 cm depth											
11/82	<0.02	<0.05	<0.05	0.07	0.14	<0.1	0.02	0.05	0.10	0.10	<0.50
6/83	<0.02	0.09	<0.05	<0.05	0.29	<0.1	<0.01	<0.05	0.14	0.89	<0.50
11/83	<0.02	<0.05	<0.05	0.06	0.08	<0.1	<0.05	<0.05	0.07	0.24	<0.50
6/84	<0.02	<0.05	<0.05	<0.05	0.09	<0.1	<0.05	<0.05	0.16	0.34	0.76
11/84	<0.02	0.15	<0.05	<0.05	0.19	<0.1	<0.05	<0.05	0.11	0.61	0.79
Treatment, unvegetated, 25-50 cm depth											
11/82	<0.02	<0.05	<0.05	0.14	0.52	<0.1	<0.01	<0.05	0.07	0.10	<0.50
6/83	<0.02	0.08	<0.05	<0.05	0.08	<0.1	<0.01	<0.05	<0.05	0.28	<0.50
11/83	<0.02	0.13	<0.05	0.13	0.32	<0.1	<0.05	0.05	0.17	0.23	0.90
6/84	<0.02	<0.05	<0.05	<0.05	0.09	<0.1	0.08	<0.05	0.14	0.16	0.68
11/84	<0.02	0.21	<0.05	<0.05	0.18	<0.1	<0.05	<0.05	0.10	0.10	0.78
Treatment, vegetated, 25-50 cm depth											
11/82	<0.02	<0.05	<0.05	0.06	0.11	<0.1	0.06	<0.05	0.06	0.10	<0.50
6/83	<0.02	0.11	0.38	0.16	0.28	0.1	0.22	<0.05	0.18	0.23	0.75
11/83	0.10	0.35	0.07	0.72	0.73	0.3	0.07	0.06	0.12	1.19	0.69
6/84	<0.02	0.24	0.07	0.11	0.43	0.1	0.21	0.08	0.44	0.67	2.37
11/84	<0.02	0.09	<0.05	0.08	0.08	<0.1	<0.05	<0.05	0.07	0.07	<0.50

TABLE A-10. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), FIELD STUDY, SITE OT.

Date	Cd	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 50-75 cm depth											
11/82	<0.02	0.05	<0.05	0.07	0.11	<0.1	<0.01	<0.05	<0.05	0.07	<0.50
6/83	<0.15	<0.05	<0.05	<0.05	0.09	0.1	0.02	<0.05	0.11	0.34	<0.50
11/83	<0.02	0.06	<0.05	0.08	0.17	<0.1	<0.50	<0.05	0.23	0.25	0.64
6/84	<0.02	<0.05	<0.05	<0.05	0.17	<0.1	<0.05	<0.05	0.22	0.40	1.08
11/84	<0.02	0.06	<0.05	<0.05	0.13	<0.1	<0.05	<0.05	0.11	0.52	0.84
Treatment, unvegetated, 50-75 cm depth											
11/82	<0.02	<0.05	<0.05	0.07	0.14	<0.1	<0.01	0.05	0.05	0.15	<0.50
6/83	<0.02	0.05	<0.05	<0.05	<0.05	<0.1	<0.01	<0.05	<0.05	0.22	<0.50
11/83	<0.02	<0.05	<0.05	0.06	0.08	<0.1	<0.05	0.06	0.11	0.24	0.97
6/84	<0.02	0.08	<0.05	0.06	0.16	<0.1	0.08	<0.05	0.19	0.43	0.83
11/84	<0.02	0.07	<0.05	<0.05	0.14	<0.1	<0.05	<0.05	0.08	0.10	0.62
Treatment, vegetated, 50-75 cm depth											
11/82	<0.02	0.06	<0.05	0.37	0.57	<0.1	<0.01	<0.05	0.06	0.11	<0.50
6/83	<0.02	0.08	<0.05	0.06	0.06	<0.1	0.02	<0.05	0.06	0.27	<0.50
11/83	<0.02	0.06	<0.05	<0.05	0.23	<0.1	0.16	<0.05	0.09	0.57	0.65
6/84	<0.02	<0.05	<0.05	0.08	0.30	<0.1	0.12	0.06	0.30	0.67	1.29
11/84	<0.02	0.08	<0.05	<0.05	0.10	<0.1	<0.05	0.05	0.07	0.06	0.62

TABLE A-11. SOIL ANALYSIS, GREENHOUSE STUDY, SITE OP.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC	Cond.
		mg/l	mg/l	ug/ml	ug/ml	mg/l	mg/l	umho/cm
Control, unvegetated, surface								
6/82	5.8	1142	183	9	23	100	9900	
11/82	5.3	1142	136	6	7	<100		
6/83	5.6	1042	187	13	9	<80	13000	1260
11/83	5.4	1031	226	6	10	<90		
6/84	5.3	1058	224	15	8	300	5400	140
Treatment, unvegetated, surface								
6/82	6.5	1259	570	10	10	44000	37000	
11/82	6.7	1623	620	10	28	34000		
6/83	6.9	1452	554	11	28	29000	22000	910
11/83	6.3	1031	623	2	21	29000		
6/84	6.7	1485	636	4	18	19000	14000	800
Treatment, vegetated, surface								
6/82	6.5	1259	570	10	10	44000	37000	
11/82	6.5	909	469	8	32	34000		
6/83	7.0	1317	540	11	36	27000	16000	490
11/83	6.8	1345	623	4	41	25000		
6/84	6.7	1485	617	3	21	26000	450	600
Control, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.8	675	183	6	3	<100		
6/83	4.4	124	103	11	2	<85	1700	37
11/83	4.4	286	211	4	3	<140		
6/84	4.1	238	148	3	1	1100	1300	42
Treatment, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.7	909	229	12	6	170		
6/83	4.6	65	108	11	3	<97	1600	88
11/83	4.5	362	137	5	3	240		
6/84	4.5	238	111	3	1	650	1100	77
Treatment, vegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.9	454	183	10	7	140		
6/83	4.6	113	82	13	3	<83	1400	225
11/83	4.6	286	131	4	4	<150		
6/84	4.6	481	105	3	1	<100	1600	170

TABLE A-12. SOIL ANALYSIS, GREENHOUSE STUDY, SITE OT.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC	Cond.
		mg/l	mg/l	ug/ml	ug/ml	mg/l	mg/l	umho/cm
Control, unvegetated, surface								
6/82	7.0	675	229	8	80	<100	8200	
11/82	7.1	675	229	8	94	170		
6/83	7.4	378	343	8	81	<79	7200	180
11/83	7.5	729	374	4	83	<110		
6/84	7.3	481	425	3	82	4600	3600	72
Treatment, unvegetated, surface								
6/82	6.8	1623	620	9	23	76000	34000	
11/82	6.8	1856	469	8	23	54000		
6/83	6.8	1884	540	13	29	44000	22000	335
11/83	6.5	1987	623	5	22	50000		
6/84	6.6	2192	626	4	18	50000	17000	190
Treatment, vegetated, surface								
6/82	6.8	1623	620	9	23	76000	34000	
11/82	6.8	1376	469	7	23	43000		
6/83	6.9	1738	501	11	40	42000	21000	280
11/83	6.6	1987	623	4	24	43000		
6/84	6.7	2284	656	3	15	25000	660	180
Control, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.6	675	136	6	3	190		
6/83	4.6	11	108	11	5	<83	1000	26
11/83	4.7	362	219	4	2	<250		
6/84	4.5	157	124	4	1	<100	900	25
Treatment, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.8	909	183	10	3	<100		
6/83	4.6	65	108	11	3	<85	1100	36
11/83	4.6	432	119	5	3	220		
6/84	4.5	319	116	4	1	<100	450	47
Treatment, vegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.7	909	183	7	6	120		
6/83	4.7	102	95	13	3	<84	1500	77
11/83	4.9	286	141	5	3	720		
6/84	4.6	238	105	4	1	<100	1400	74

TABLE A-13. SOIL ANALYSIS, GREENHOUSE STUDY, SITE TX.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC	Cond.
		mg/1	mg/1	ug/ml	ug/ml	mg/1	mg/1	umho/cm
Control, unvegetated, surface								
6/82	7.7	909	136	9	9	1900	22000	
11/82	7.5	675	90	6	6	1600		
6/83	7.6	378	82	8	6	1600	9500	500
11/83	7.6	583	131	5	7	1800		
6/84	7.4	643	136	3	6	7400	5500	325
Treatment, unvegetated, surface								
6/82	5.5	1376	372	15	5	84000	57000	
11/82	6.2	1376	229	6	4	47000		
6/83	6.7	124	362	11	2	58000	25000	2770
11/83	6.3	1345	497	5	3	55000		
6/84	6.3	1312	326	9	1	35000	20000	2710
Treatment, vegetated, surface								
6/82	5.5	1376	372	15	5	84000	57000	
11/82	5.9	1025	229	16	4	75000		
6/83	6.8	1452	371	13	2	47000	28000	2650
11/83	6.8	1188	452	5	2	36000		
6/84	6.7	1836	402	6	1	48000	22000	2250
Control, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.7	454	90	7	4	<100		
6/83	4.8	65	143	10	3	<85	1800	47
11/83	4.5	362	204	4	4	<100		
6/84	4.0	972	170	1	1	9000	1100	39
Treatment, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.5			7	3	270		
6/83				0	2	<200	1700	250
11/83	4.6	508	176	5	2	160		
6/84	4.6	238	122	6	1	730	1200	330
Treatment, vegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.6	675	183	12	4	<100		
6/83	5.4	124	102	10	3	<85	1300	360
11/83	4.9	362	116	5	3	<120		
6/84	5.2	238	81	4	1	<100	1300	340

TABLE A-14. SOIL ANALYSIS, GREENHOUSE STUDY, SITE WA.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC	Cond.
		mg/l	mg/l	ug/ml	ug/ml	mg/l	mg/l	umho/cm
Control, unvegetated, surface								
6/82	4.8	909	275	10	18	210	17000	
11/82	4.9	1376	275	7	7	190		
6/83	4.9	1042	362	10	3	<79	15000	105
11/83	5.1	1264	384	5	9	<90		
6/84	5.0	1312	425	6	6	<100	800	86
Treatment, unvegetated, surface								
6/82	4.9	1142	519	9	7	38000	47000	
11/82	4.8	1623	519	9	9	43000		
6/83	4.7	1598	554	16	6	35000	31000	1000
11/83	4.7	2149	571	6	3	38000		
6/84	4.5	1922	598	4	1	35000	24000	1170
Treatment, vegetated, surface								
6/82	4.9	1142	519	9	7	38000	47000	
11/82	4.7	1623	570	10	6	49000		
6/83	5.0	1512	547	13	5	35000	30000	560
11/83	5.0	1501	632	2	5	32000		
6/84	4.6	1658	572	4	2	31000	22000	620
Control, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.6	675	136	7	3	130		
6/83	4.5	124	82	10	3		1100	31
11/83	4.6	729	144	4	3	110		
6/84	4.4	157	94	4	1	9100	1000	77
Treatment, unvegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.7	675	229	10	6	<100		
6/83	4.4	27	129	13	3	<95	1600	61
11/83	4.4	362	190	5	2	120		
6/84	4.4	157	59	6	1	<100	990	71
Treatment, vegetated, subsurface								
6/82	4.8	675	229	9		<100	1200	
11/82	4.8	909	275	10	4	170		
6/83					5	<85	2000	250
11/83	4.3	653	187	5	5	<200		
6/84	4.4	157	71	4	1	<100	1100	185

TABLE A-15. SOIL ANALYSIS, FIELD STUDY, SITE OT.

Date	pH	Tot N mg/l	Tot P mg/l	NH_4-N ug/ml	Exch P ug/ml	O & G mg/l	TOC mg/l	Cond. umho/cm
Control, unvegetated, 0-25 cm depth								
11/82	7.0	675	207	13	49	<100	6500	
6/83	7.0	442	326	6	77	<85	6300	89
11/83	7.2	583	374	2	75	1500		
6/84	7.2	3127	381	4	56	5800	2600	62
11/84	7.1	491	396	3	64	120		
Treatment, unvegetated, 0-25 cm depth								
11/82	7.3	1713	337	11	18	90000	41000	
6/83	7.0	1955	554	10	23	78000	23000	180
11/83	6.9	1345	614	2	27	59000		
6/84	6.9	2014	677	5	29	49000	2400	165
11/84	6.9	1750	695	5	27	71000		
Treatment, vegetated, 0-25 cm depth								
11/82	7.1	1713	359	11	16	91000	46000	
6/83	7.0	1452	486	10	41	40000	23000	100
11/83	6.8	1820	623	5	25	66000		
6/84	6.9	2376	656	6	27	47000	450	105
11/84	6.9	2101	706	3	26	57000		
Control, unvegetated, 25-50 cm depth								
11/82	7.1	506	123	13	22	<100	2000	
6/83	7.1	124	227	6	28	<85	6300	54
11/83	7.0	216	250	2	13	<90		
6/84	6.9	319	278	6	24	7000	1900	22
11/84	6.8	243	296	1	22	<100		
Treatment, unvegetated, 25-50 cm depth								
11/82	8.4	675	123	15	11	170	2800	
6/83	8.2	113	150	10	9	1500	2200	105
11/83	7.2	216	219	4	10	360		
6/84	7.1	319	262	4	13	130	1600	53
11/84	7.1	184	239	1	9	140		
Treatment, vegetated, 25-50 cm depth								
11/82	8.3	844	165	8	14	800	2500	
6/83	7.3	124	211	6	16	<85	1400	58
11/83	7.5	216	270	2	19	<90		
6/84	7.8	319	295	4	13	<100	2300	80
11/84	7.4	119	250	1	7	2100		

TABLE A-15. (CONTINUED) SOIL ANALYSIS, FIELD STUDY, SITE OT.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC	Cond.
		mg/1	mg/1	ug/ml	ug/ml	mg/1	mg/1	umho/cm
Control, unvegetated, 50-75 cm depth								
11/82	6.9	337	123	6	18	<100	1300	
6/83	6.9	5	197	8	14	<85	1100	38
11/83	7.0	216	266	2	12	520		
6/84	7.2	319	295	9	24	<100	1200	36
11/84	6.9	243	283	1	12	110		
Treatment, unvegetated, 50-75 cm depth								
11/82	8.5	337	123	8	14	<100	1100	
6/83	8.0	75	157	6	3	<85	690	89
11/83	7.5	146	219	2	7	<90		
6/84	7.0	238	239	3	6	<100	1000	25
11/84	7.1	243	250	1	8	120		
Treatment, vegetated, 50-75 cm depth								
11/82	7.8	675	207	6	9	230	2300	
6/83	7.0	27	211	10	9	<85	1200	53
11/83	6.9	216	258	2	13	140		
6/84	7.9	238	270	4	8	<100	1000	50
11/84	7.5	119	266	1	5	<100		

TABLE A-16. RUNOFF ANALYSIS (MG/L), FIELD STUDY, SITE OT.

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Se	Cd
Control, unvegetated, unfiltered											
11/82	8.2	24.0	30	9.9	19.00	0.74	<0.01	<0.010	19.00	<0.030	<0.003
6/83	5.4	11.1	42	9.3	21.77	0.79	<0.01	<0.010	24.12	<0.030	<0.003
11/83	5.6	16.0	45	16.0	47.00	1.70	0.03	0.003	43.00	0.030	0.005
6/84	6.0	13.0	36	5.2	6.30	0.32	<0.01	<0.010	6.10		<0.003
11/84	6.4	7.1	36	6.1	5.60	0.18	<0.01	<0.010	5.30		<0.003
Control, unvegetated, filtered											
11/82	9.6	21.0	29	4.6	0.74	0.25	<0.01	<0.010	0.84	<0.030	<0.003
6/83	5.9	3.3	30	2.3	0.38	0.05	<0.01	<0.010	0.51	<0.030	<0.003
11/83	8.1	5.3	27	2.6	1.10	0.06	<0.01	<0.010	0.04	0.006	0.002
6/84	6.9	8.7	33	3.0	0.37	0.06	<0.01	<0.010	0.30		<0.003
11/84	7.4	5.2	34	4.6	0.19	0.01	<0.01	<0.010	0.13		<0.003
Treatment, unvegetated, unfiltered											
11/82	6.6	4.0	52	4.1	6.30	0.15	<0.01	<0.010	0.97	<0.030	<0.003
6/83	5.5	3.6	47	3.4	5.77	0.22	<0.01	<0.010	5.34	<0.030	<0.003
11/83	4.7	3.4	58	4.2	11.00	0.40	<0.01	<0.010	9.70	<0.005	0.002
6/84	8.2	7.3	54	4.4	7.10	0.30	<0.01	<0.010	6.60	<0.003	<0.003
11/84	6.2	4.5	59	4.9	6.30	0.30	<0.01	<0.010	5.80		<0.003
Treatment, unvegetated, filtered											
11/82	7.4	2.0	34	2.0	1.30	0.14	<0.01	<0.010	0.45	<0.030	<0.003
6/83	5.0	1.6	32	1.9	<0.10	0.02	<0.01	<0.010	<0.01	<0.030	<0.003
11/83	5.3	1.2	30	1.7	0.88	0.12	<0.01	<0.003	0.47	<0.004	<0.001
6/84	7.6	5.7	38	2.8	0.21	0.09	<0.01	<0.010	0.15		<0.003
11/84	6.6	3.3	42	3.4	0.14	0.09	<0.01	<0.010	<0.10		<0.003
Treatment, vegetated, unfiltered											
11/82	7.8	3.3	36	2.9	3.00	0.14	<0.01	<0.010	1.40	<0.030	<0.003
6/83	4.6	9.9	38	3.8	1.65	0.10	<0.01	<0.010	0.89	<0.030	<0.003
11/83	4.8	2.1	31	2.3	2.00	0.09	<0.01	<0.010	0.07	<0.004	<0.001
6/84	7.3	7.7	42	3.6	3.10	0.13	<0.01	<0.010	2.50		<0.003
11/84	6.6	5.9	41	6.6	9.50	0.20	<0.01	<0.010	11.50		<0.003
Treatment, vegetated, filtered											
11/82	7.6	3.0	34	2.6	1.10	0.11	<0.01	<0.010	0.34	<0.030	<0.003
6/83	4.8	7.6	34	3.4	0.19	0.07	<0.01	<0.010	0.19	<0.030	<0.003
11/83	5.7	1.9	28	2.1	0.18	0.08	<0.01	<0.003	0.03	<0.004	<0.001
6/84	7.9	7.2	37	2.9	0.17	0.08	<0.01	<0.010	0.17		<0.003
11/84	9.7	3.7	35	3.7	0.12	0.01	<0.01	<0.010	0.21		<0.003

TABLE A-16. (CONTINUED) RUNOFF ANALYSIS (MG/L), FIELD STUDY, SITE OT.

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, unfiltered										
11/82	0.05	0.052	0.02	0.26	0.08	0.07	<0.01	0.26	0.05	0.37
6/83	0.04	0.052	0.02	0.34	0.09	0.12	0.04	0.30	0.04	0.47
11/83	0.06	0.080	0.05	0.64	0.12	0.12	0.07	0.45	0.02	0.66
6/84	0.01	0.020	<0.01	0.28	0.05	0.01	<0.01	0.01	0.01	0.10
11/84	0.02	0.010	<0.01	0.21	0.02	0.15	<0.01	0.11	0.04	0.16
Control, unvegetated, filtered										
11/82	<0.01	<0.010	<0.01	0.14	0.01	0.06	<0.01	0.11	0.08	<0.10
6/83	0.02	<0.010	<0.01	0.03	<0.02	0.08	<0.01	0.05	0.03	<0.10
11/83	<0.01	<0.002	<0.01	0.03	0.01	0.06	<0.01	<0.01	0.05	0.03
6/84	<0.01	<0.010	<0.01	0.11	<0.02	0.08	<0.01	0.06	<0.01	<0.10
11/84	<0.01	<0.010	<0.01	0.04	<0.02	0.14	<0.01	0.04	0.04	<0.10
Treatment, unvegetated, unfiltered										
11/82	0.02	0.028	<0.01	0.27	0.03	0.07	<0.01	0.05	0.05	<0.10
6/83	0.07	0.120	<0.01	0.37	0.09	0.15	0.01	0.14	0.01	0.13
11/83	0.13	0.250	0.02	0.87	0.11	0.17	0.02	0.18	<0.01	0.18
6/84	0.07	0.150	<0.01	0.52	0.07	0.18	<0.01	0.18	<0.01	0.12
11/84	0.08	0.140	<0.01	0.50	0.07	0.22	<0.01	0.17	0.03	0.12
Treatment, unvegetated, filtered										
11/82	0.02	<0.010	<0.01	0.26	0.02	0.07	<0.01	0.04	0.05	<0.10
6/83	0.02	<0.010	<0.01	0.02	<0.02	0.11	<0.01	0.05	0.02	<0.10
11/83	0.02	0.020	<0.01	0.13	<0.02	0.10	<0.01	0.02	<0.01	<0.01
6/84	0.01	<0.010	<0.01	0.08	<0.02	0.13	<0.01	0.06	0.02	<0.10
11/84	0.02	<0.010	<0.01	0.06	<0.02	0.18	<0.01	0.05	0.01	<0.10
Treatment, vegetated, unfiltered										
11/82	0.03	0.028	<0.01	0.36	0.08	0.12	<0.01	0.05	0.20	<0.10
6/83	0.03	0.020	<0.01	0.15	0.04	0.14	<0.01	0.07	0.02	<0.10
11/83	0.02	0.020	<0.01	0.11	<0.02	0.10	<0.01	<0.01	<0.01	0.01
6/84	0.02	0.050	<0.01	0.23	0.03	0.15	<0.01	0.10	<0.01	<0.10
11/84	0.03	0.040	<0.01	0.34	<0.02	0.19	0.02	0.18	0.02	0.14
Treatment, vegetated, filtered										
11/82	0.03	<0.010	<0.01	0.28	0.04	0.11	<0.01	0.04	0.17	<0.10
6/83	0.03	<0.010	<0.01	0.05	<0.02	0.13	<0.01	0.05	0.02	<0.10
11/83	0.02	<0.010	<0.01	0.19	<0.02	0.09	<0.01	<0.01	<0.01	<0.10
6/84	0.01	<0.010	<0.01	0.07	<0.02	0.14	<0.01	0.05	0.30	<0.10
11/84	<0.01	<0.010	<0.01	0.03	<0.02	0.15	<0.01	0.04	0.03	<0.10

TABLE A-16. (CONTINUED) RUNOFF ANALYSIS, FIELD STUDY, SITE OT.

Date	pH	Tot N	Tot P	NH_4-N	Exch P	O & G	TOC
		mg/l	mg/l	ug/ml	ug/ml	mg/l	mg/l
Control, unvegetated, unfiltered							
11/82	5.1	8.4	1.0	3.6	0.7	<10	6
6/83	6.0	22.1	0.04		0.04	<3	15
11/83	7.1	30.8	5.8	0.1	0.4	<5	
6/84	6.0	36.0	6.4	26.5	1.4	2	1
11/84	6.7	23.8	1.3	0.9	0.5	<10	
Control, unvegetated, filtered							
11/82	2.6	8.4	4.1	2.7	0.7	<10	0
6/83	6.2	65.8	0.1	0.1	0.1	<3	31
11/83	7.2	52.4	1.0		0.2	<5	
6/84	6.5	9.7	0.6	0.9	0.5	<5	25
11/84	7.1	11.9	0.9	0.3	0.4	<10	
Treatment, unvegetated, unfiltered							
11/82	2.5	16.9	2.0	2.4	0.2	<10	6
6/83	6.5	58.8	0.05		0.04	<3	10
11/83	7.3	15.1	1.2	0.0	0.3	17	
6/84	0.2	33.2	1.9	0.6	0.4	9	67
11/84	6.5	11.9	0.9	0.6	0.2	<10	
Treatment, unvegetated, filtered							
11/82	2.0	33.7	3.1	5.1	0.2	<10	0
6/83	6.7	18.9	0.01			10	23
11/83	6.9	11.9	0.4	0.1	0.2	<5	
6/84	6.7	43.5	1.0	1.2	0.4	<5	24
11/84	6.9	36.7	0.4	0.6	0.2	<10	
Treatment, vegetated, unfiltered							
11/82	2.9	16.9	2.0	2.7	0.4	11	23
6/83	6.5	24.3	0.2		0.2	<3	20
11/83	7.4	30.8	0.7		0.3	<5	
6/84	6.7	29.7	0.4	0.7	0.4	<5	29
11/84	6.5	11.9	0.4	0.5	0.2	<10	
Treatment, vegetated, filtered							
11/82	2.2	16.9	2.0	3.9	0.4	<10	0
6/83	6.5	17.8	0.3		0.2	<3	24
11/83	2.9	12.2	0.7		0.2	<5	
6/84	6.4	36.7	0.4	0.6	0.4	6	36
11/84	6.8	60.5	0.2	0.2	0.1	<10	

TABLE A-17. VEGETATION ANALYSIS (MG/KG)

Date	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Site OT, field										
11/83	237	8570	9740	2120	327	39	<0.3	0.7	194	0.25
11/84	154	7267	8307	1424	365	34	<0.2	0.2	298	0.21
Site OP, greenhouse										
11/83	228	10112	9463	2775	80	892	0.5	<1.0	59	0.40
6/84	152	14220	8133	3226	2833	555	2.5	1.7	4768	0.83
Site OT, greenhouse										
11/83	188	13310	6066	2383	110	134	<0.7	1.0	91	<0.07
6/84	217	17616	8408	3026	598	201	1.0	1.8	848	0.23
Site TX, greenhouse										
11/83	202	12903	8925	4044	92	539	<0.4	5.4	52	0.13
6/84	163	17948	7663	4149	696	395	1.1	8.1	700	0.70
Site WA, greenhouse										
11/83	165	12692	7724	4061	215	444	<4.2	<4.2	228	<1.22
6/84	162	14031	3431	2354	81	355	<3.5	<3.5	69	<1.00

TABLE A-17. (CONTINUED) VEGETATION ANALYSIS (MG/KG)

Date	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Site OT, field										
11/83	6.2	5.2	1.8	178	4.8	32	0.4	34	66.0	4.4
11/84	8.2	5.7	17.3	225	6.4	27	0.7	42	6.2	4.9
Site OP, greenhouse										
11/83	6.9	1.7	2.8	118	<2.1	41	<1.1	6	8.2	<10.6
6/84	11.0	7.0	23.0	145	27.0	38	6.4	38	12.0	21.0
Site OT, greenhouse										
11/83	8.3	1.7	2.0	111	0.7	21	<0.7	11	8.6	<7.0
6/84	16.0	2.3	26.0	191	23.0	33	1.3	27	15.0	7.2
Site TX, greenhouse										
11/83	11.2	1.0	5.2	213	0.9	23	<1.0	3	11.3	<10.5
6/84	12.0	1.8	19.0	181	19.0	21	1.8	7	13.0	<5.1
Site WA, greenhouse										
11/83	7.7	<4.2	20.6	136	<8.3	105	<4.2	11	21.5	<41.5
6/84	9.1	<3.5	6.6	98	<7.0	32	<3.5	5	25.0	<34.0

TABLE A-18. ORGANICS (MG/KG), GREENHOUSE STUDY.

Location	Date	Organic fraction										
		TCOLCH	TCOLCA	TCOLCX	TCOSUM	TCOTOE	GRVLCH	GRVLCA	GRVLCX	GRVSUM	GRVTOE	TCO+GRV
Control, unvegetated, surface												
OP	6/82					43					265	308
OP	11/82					200					320	520
OP	6/83					LDL					160	160
OP	11/83					20					300	320
OP	6/84					LDL					450	450
Treatment, unvegetated, surface												
OP	6/82	900	2700	LDL	3600	4200	18000	23000	6500	47500	48000	52200
OP	11/82	61	320	LDL	380	420	21000	12000	8500	42000	42000	42420
OP	6/83	40	40	LDL	80	100	12400	16700	7900	37000	37000	37100
OP	11/83	LDL	650	LDL	650	430	11400	17700	7400	36500	39200	39630
OP	6/84	LDL	LDL	260	260	860	22500	9300	8000	39800	40500	41360
Treatment, vegetated, surface												
OP	6/82	900	2700	LDL	3600	4200	18000	23000	6500	47500	48000	52200
OP	11/82					270					30900	31170
OP	6/83	LDL	LDL	LDL	LDL	220	12500	15000	7600	35100	35000	35220
OP	11/83					110					32800	32910
OP	6/84	LDL	500	300	800	500	9500	19000	9100	37600	36000	36500
Control, unvegetated, subsurface												
OP	6/84					3					100	103
Treatment, unvegetated, subsurface												
OP	6/83					LDL					80	80
OP	6/84					LDL					200	200
Treatment, vegetated, subsurface												
OP	6/84					LDL					100	100

TABLE A-18. (CONTINUED) ORGANICS (MG/KG), GREENHOUSE STUDY.

Location	Date	Organic fraction TCOLCH	TCOLCA	TCOLCX	TCOSUM	TCOTOE	GRVLCH	GRVLCA	GRVLCX	GRVSUM	GRVTOE	TCO+GRV
Control, unvegetated, surface												
OT	6/82					11					130	141
OT	11/82					19					190	209
OT	6/83					LDL					150	150
OT	11/83					LDL					200	200
OT	6/84					LDL					200	200
Treatment, unvegetated, surface												
OT	6/82	LDL	LDL	LDL	LDL	170	32000	15000	12000	59000	58000	58170
OT	11/82	130	LDL	LDL	130	140	32000	8000	19000	59000	60000	60140
OT	6/83	LDL	LDL	LDL	LDL	180	28500	4600	12500	45600	48000	48180
OT	11/83	LDL	LDL	LDL	LDL	50	19600	17500	14700	51800	52500	52550
OT	6/84	LDL	540	LDL	540	960	18500	22000	11000	51500	55500	56460
Treatment, vegetated, surface												
OT	6/82	LDL	LDL	LDL	LDL	170	32000	15000	12000	59000	58000	58170
OT	11/82					180					59000	59180
OT	6/83	110	LDL	LDL	110	200	29000	4800	9100	42900	49000	49200
OT	11/83					60					52500	52560
OT	6/84	LDL	LDL	340	340	270	19500	20000	15000	54500	58500	58770
Control, unvegetated, subsurface												
OT	6/84					3					100	103
Treatment, unvegetated, subsurface												
OT	6/83					LDL					80	80
OT	6/84					LDL					150	150
Treatment, vegetated, subsurface												
OT	6/84					1					200	201

TABLE A-18. (CONTINUED) ORGANICS (MG/KG), GREENHOUSE STUDY.

Location	Date	Organic fraction										
		TCOLCH	TCOLCA	TCOLCX	TCOSUM	TCOTOE	GRVLCH	GRVLCA	GRVLCX	GRVSUM	GRVTOE	TCO+GRV
Control, unvegetated, surface												
TX	6/82					26					3520	3546
TX	11/82					180					3300	3480
TX	6/83	LDL	LDL	LDL	LDL	LDL	1600	800	800	3200	3600	3600
TX	11/83					10					3000	3010
TX	6/84	LDL	LDL	LDL	LDL	LDL	1400	1200	1000	3600	3800	3800
Treatment, unvegetated, surface												
TX	6/82	1100	700	LDL	1800	1700	46000	22000	11000	79000	65000	66700
TX	11/82	3000	1800	88	4900	3000	53000	6600	11000	71000	71400	74400
TX	6/83	980	60	LDL	1040	1400	37000	11000	11000	59000	66500	67900
TX	11/83	300	400	200	900	1100	30600	16900	10800	58300	66700	67800
TX	6/84	700	LDL	300	1000	1200	33500	17000	12000	62500	66000	67200
Treatment, vegetated, surface												
TX	6/82	1100	700.	LDL	1800	1700	46000	22000	11000	79000	65000	66700
TX	11/82					4100					70000	74100
TX	6/83	500	LDL	LDL	500	1200	26500	5800	9800	42100	44500	45700
TX	11/83					330					48400	48730
TX	6/84	180	190	240	610	1300	21500	11000	11000	41500	54000	55300
Control, unvegetated, subsurface												
TX	6/84					LDL					100	100
Treatment, unvegetated, subsurface												
TX	6/83					LDL					20	20
TX	6/84					LDL					200	200
Treatment, vegetated, subsurface												
TX	6/84					2					250	252

TABLE A-18. (CONTINUED) ORGANICS (MG/KG), GREENHOUSE STUDY.

Location	Date	Organic fraction TCOLCH	TCOLCA	TCOLCX	TCOSUM	TCOTOE	GRVLCH	GRVLCA	GRVLCX	GRVSUM	GRVTOE	TCO+GRV
Control, unvegetated, surface												
WA	6/82					6					210	216
WA	11/82					40					130	170
WA	6/83					LDL					120	120
WA	6/84					LDL					400	400
Treatment, unvegetated, surface												
WA	6/82	2500	2200	LDL	4700	3700	22000	18000	9000	49000	50000	53700
WA	11/82	3200	LDL	45	3245	3500	26000	8000	9000	43000	45000	48500
WA	6/83	200	360	LDL	560	2700	17000	13000	7600	37500	42000	44700
WA	11/83	600	400	300	1300	1700	21000	20000	10500	51500	65000	66700
WA	6/84	670	900	250	1800	3800	18500	13000	8700	40200	45500	49300
Treatment, vegetated, surface												
WA	6/82	2500	2200	LDL	4700	3700	22000	18000	9000	49000	50000	53700
WA	11/82					4300					44000	48300
WA	6/83	1500	550	LDL	2000	2600	13500	13000	7600	34000	40500	43100
WA	11/83										41400	41400
WA	6/84	LDL	LDL	270	270	410	13500	13500	8500	35500	42500	42910
Control, unvegetated, subsurface												
WA	6/84					10					100	110
Treatment, unvegetated, subsurface												
WA	6/83					175					20	195
WA	6/84					LDL					100	100
Treatment, vegetated, subsurface												
WA	6/84		LDL								50	50

TABLE A-19. ORGANICS (MG/KG), FIELD STUDY.

Location	Date	TCOLCH	TCOLCA	TCOLCX	TCOSUM	TCOTOE	GRVLCH	GRVLCA	GRVLCX	GRVSUM	GRVTOE	TCO+GRV
		Organic fraction										
Control, unvegetated, 0-25 cm depth												
OT	6/83				LDL						110	110
OT	11/83	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	200	200
OT	6/84					3					200	203
OT	11/84					LDL					230	230
Treatment, unvegetated, 0-25 cm depth												
OT	6/83	690	LDL	LDL	690	480	40500	5500	13500	59500	65500	65980
OT	11/83	LDL	240	270	510	120	29000	14000	15000	58000	62500	62620
OT	6/84					LDL					49000	49000
OT	11/84	LDL	LDL	LDL	LDL	2400	36000	19000	16000	71000	74000	76400
Treatment, vegetated, 0-25 cm depth												
OT	6/83					175					45000	45175
OT	11/83	LDL	900	LDL	900	190	22500	18000	16300	56800	60100	60290
OT	6/84					LDL					67000	67000
OT	11/84	LDL	LDL	LDL	LDL	390	30000	22000	17000	69000	72000	72390
Control, unvegetated, 25-50 cm depth												
OT	6/82					0.1					53	53
OT	11/83					LDL					50	50
Treatment, unvegetated, 25-50 cm depth												
OT	6/82					LDL					260	260
OT	6/83				LDL	1					130	131
OT	11/83					LDL					100	100
OT	6/84					LDL					250	250
OT	11/84					LDL					170	170
Treatment, vegetated, 25-50 cm depth												
OT	11/84					LDL					1700	1700

TABLE B-1. TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, surface										
OP1	87	3248	1659	2297	14719	307	6.2	<1.7	21412	0.27
OP2	79	3060	1595	2173	14434	309	6.4	<1.6	20002	<0.26
Mean	83	3154	1627	2235	14577	308	6.3	<1.7	20707	<0.27
Std dev	6	133	45	88	202	1	0.1	0.1	997	0.01
Treatment, unvegetated, surface										
OP1	167	2511	6071	2494	19279	376	7.1	2.1	19416	0.50
OP2	188	2363	5619	2462	19167	342	7.5	<1.5	18506	0.34
OP3	194	2187	6218	2429	19481	372	7.0	<1.4	17004	0.46
Mean	183	2354	5969	2462	19309	363	7.2	<1.7	18309	0.43
Std dev	14	162	312	33	159	19	0.3	0.4	1218	0.08
Treatment, vegetated, surface										
OP1	120	2195	6897	2265	18261	348	7.1	<1.5	17679	0.49
OP2	139	2275	5864	2339	18108	392	7.5	<1.4	17371	0.56
OP3	143	2439	5391	2361	19067	306	6.6	<1.6	18741	0.47
Mean	134	2303	6051	2322	18479	349	7.1	<1.5	17930	0.51
Std dev	12	124	770	50	515	43	0.5	0.1	719	0.05
Control, unvegetated, surface										
OT1	70	1564	4351	2143	7717	178	3.2	<1.0	7686	<0.29
OT2	83	1571	4612	2241	7653	187	3.2	<0.9	7966	<0.26
Mean	77	1568	4482	2192	7685	183	3.2	<0.9	7826	<0.28
Std dev	9	5	185	69	45	6	0.0	0.1	198	0.02
Treatment, unvegetated, surface										
OT1	162	1860	18205	2337	8163	172	3.4	1.1	9574	0.43
OT2	209	2077	20467	2442	8362	153	2.9	<1.0	9703	0.44
OT3	191	2275	18808	2397	8131	167	3.6	<1.0	9271	0.35
Mean	187	2071	19160	2392	8219	164	3.3	<1.0	9516	0.41
Std dev	24	208	1171	53	125	10	0.4	0.1	222	0.05
Treatment, vegetated, surface										
OT1	221	2192	19134	2429	8594	177	3.4	<1.0	10387	0.41
OT2	214	1925	19922	2396	7968	160	3.3	1.0	9247	0.43
OT3	198	1970	18067	2368	9110	178	3.6	1.0	9945	0.46
Mean	211	2029	19041	2398	8557	172	3.4	<1.0	9860	0.43
Std dev	12	143	931	31	572	10	0.2	0.0	575	0.03

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, surface										
TX1	121	1255	16358	2279	12216	184	15.0	36.0	16011	0.25
TX2	141	1733	12247	2371	12237	165	17.0	45.0	19407	<0.21
Mean	131	1494	14303	2325	12227	175	16.0	40.5	17709	<0.23
Std dev	14	338	2907	65	15	13	1.4	6.4	2401	0.03
Treatment, unvegetated, surface										
TX1	800	1563	36791	4149	21530	210	23.0	45.0	20170	0.92
TX2	875	2111	35473	4205	22950	234	26.0	56.0	26019	0.81
TX3	874	1181	32378	3423	19378	201	23.0	50.0	15750	0.76
Mean	850	1618	34881	3926	21286	215	24.0	50.3	20646	0.83
Std dev	43	467	2265	436	1798	17	1.7	5.5	5151	0.08
Treatment, vegetated, surface										
TX1	560	1974	30624	3798	22373	206	25.0	49.0	24869	0.86
TX2	659	2133	32224	4248	22735	211	25.0	52.0	26617	0.90
TX3	539	2225	30301	3966	22794	206	25.0	49.0	27359	0.86
Mean	586	2111	31050	4004	22634	208	25.0	50.0	26282	0.87
Std dev	64	127	1030	227	228	3	0.0	1.7	1278	0.02
Control, unvegetated, surface										
WA1	285	706	4505	4607	20740	328	8.0	<1.3	19660	<0.28
WA2	250	600	3968	4343	20471	334	7.8	<1.2	17846	<0.27
Mean	268	653	4237	4475	20606	331	7.9	<1.3	18753	<0.28
Std dev	25	75	380	187	190	4	0.1	0.1	1283	0.01
Treatment, unvegetated, surface										
WA1	419	1347	6182	7016	29029	317	12.0	2.3	17628	0.38
WA2	499	1579	6730	6347	28095	319	12.0	2.1	18045	0.35
WA3	518	1545	6741	6633	28475	323	12.0	2.1	18020	0.42
Mean	479	1490	6551	6665	28533	320	12.0	2.2	17898	0.38
Std dev	53	125	320	336	470	3	0.0	0.1	234	0.04
Treatment, vegetated, surface										
WA1	479	1408	5889	6400	26995	299	12.0	<1.8	17517	0.27
WA2	365	1262	5315	6004	26489	277	11.0	2.3	16539	0.34
WA3	431	1413	5550	6439	26937	283	11.0	2.4	17739	0.34
Mean	425	1361	5585	6281	26807	286	11.3	<2.2	17265	0.32
Std dev	57	86	289	241	277	11	0.6	0.3	638	0.04

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, subsurface										
OP1	52	2343	132	2893	38707	326	14.0	<4.0	51006	<0.28
OP2	47	2119	116	2798	38912	330	14.0	<4.6	58541	<0.27
Mean	50	2231	124	2846	38810	328	14.0	<4.3	54774	<0.28
Std dev	4	158	11	67	145	3	0.0	0.4	5328	0.01
Treatment, unvegetated, subsurface										
OP1	17	2281	325	2583	31313	260	11.0	<2.3	37418	<0.28
OP2	60	2347	314	2675	31015	283	11.0	<2.8	37310	<0.29
OP3	78	2353	333	2883	34359	393	15.0	<3.0	38402	<0.27
Mean	52	2327	324	2714	32229	312	12.3	<2.7	37710	<0.28
Std dev	31	40	10	154	1851	71	2.3	0.4	602	0.01
Treatment, vegetated, subsurface										
OP1	54	2392	501	2698	29057	246	11.1	<2.7	35317	<0.23
OP2	86	2335	486	2681	30443	237	11.0	<2.8	36729	<0.26
OP3	76	2077	462	2517	29955	224	9.6	<2.4	31173	<0.26
Mean	72	2268	483	2632	29818	236	10.6	<2.6	34406	<0.25
Std dev	16	168	20	100	703	11	0.8	0.2	2888	0.02
Control, unvegetated, subsurface										
OT1	42	2389	115	2848	37688	342	14.0	<2.8	44798	<0.28
OT2	41	2003	238	2355	34496	235	11.0	<3.0	49402	<0.20
Mean	42	2196	177	2602	36092	289	12.5	<2.9	47100	<0.24
Std dev	1	273	87	349	2257	76	2.1	0.1	3256	0.06
Treatment, unvegetated, subsurface										
OT1	66	1972	259	2599	34636	308	14.0	<3.1	49496	<0.29
OT2	33	2033	282	2448	29344	278	10.3	<2.0	30701	<0.27
OT3	43	1982	224	2312	29702	265	11.0	<2.2	34958	<0.29
Mean	47	1996	255	2453	31227	284	11.8	<2.4	38385	<0.28
Std dev	17	33	29	144	2957	22	2.0	0.6	9855	0.01
Treatment, vegetated, subsurface										
OT1	76	1964	325	2467	34032	280	15.0	<3.0	48056	<0.28
OT2	85	1888	403	2510	33875	252	14.0	<3.7	58376	<0.29
OT3	88	1907	347	2383	33160	244	13.0	<3.3	54253	<0.29
Mean	83	1920	358	2453	33689	259	14.0	<3.3	53562	<0.29
Std dev	6	40	40	65	465	19	1.0	0.4	5195	0.01

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, subsurface										
TX1	61	2574	197	2972	38827	455	16.0	<4.3	55723	<0.27
TX2	60	2308	279	2888	40845	388	16.0	<4.4	56163	<0.25
Mean	61	2441	238	2930	39836	422	16.0	<4.4	55943	<0.26
Std dev	1	188	58	59	1427	47	0.0	0.1	311	0.01
Treatment, unvegetated, subsurface										
TX1	119	2340	737	2967	34088	326	12.0	<2.5	40099	<0.28
TX2	173	2318	641	2730	32008	315	10.0	<2.5	25223	<0.27
TX3	161	2487	465	2797	31671	347	12.0	<2.7	26770	<0.23
Mean	151	2382	614	2831	32589	329	11.3	<2.6	30697	<0.26
Std dev	28	92	138	122	1309	16	1.2	0.1	8179	0.03
Treatment, vegetated, subsurface										
TX1	174	2283	560	2722	31571	210	11.0	<4.2	43534	<0.26
TX2	187	2547	585	2910	33124	295	14.0	<5.1	53281	<0.30
TX3	138	2126	688	2543	30531	219	10.0	<3.5	35270	<0.26
Mean	166	2319	611	2725	31742	241	11.7	<4.3	44028	<0.27
Std dev	25	213	68	184	1305	47	2.1	0.8	9016	0.02
Control, unvegetated, subsurface										
WA1	38	1563	195	2175	27353	253	11.0	<2.3	36928	<0.28
WA2	38	2116	115	2512	31951	251	11.0	<2.3	36373	<0.26
Mean	38	1840	155	2344	29652	252	11.0	<2.3	36651	<0.27
Std dev	0	391	57	238	3251	1	0.0	0.0	392	0.01
Treatment, unvegetated, subsurface										
WA1	17	2137	221	2805	34865	323	13.0	<2.5	39522	<0.27
WA2										
WA3	28	2379	204	2852	34369	309	12.0	<2.3	37192	<0.27
Mean	23	2258	213	2829	34617	316	12.5	<2.4	38357	<0.27
Std dev	8	171	12	33	351	10	0.7	0.1	1648	0.00
Treatment, vegetated, subsurface										
WA1	46	2216	337	2535	33875	382	13.0	<3.1	30608	<0.27
WA2	67	2316	340	2673	33798	364	12.0	<23.0	29759	<0.27
WA3	39	2455	298	2626	33438	383	15.0	<3.1	32023	<0.25
Mean	51	2329	325	2611	33704	376	13.3	<9.7	30797	<0.26
Std dev	15	120	23	70	233	11	1.5	11.5	1144	0.01

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
OP1	9.7	20.0	11.6	51.0	16	19.0	37	130	16.6	437
OP2	9.6	19.0	11.0	48.0	15	18.0	34	125	7.8	390
Mean	9.7	19.5	11.3	49.5	16	18.5	36	128	12.2	414
Std dev	0.1	0.7	0.4	2.1	1	0.7	2	4	6.2	33
Treatment, unvegetated, surface										
OP1	149.0	301.0	20.0	231.0	638	75.0	33	216	1.9	310
OP2	143.0	255.0	19.0	227.0	628	74.0	27	197	5.6	134
OP3	163.0	303.0	21.0	237.0	715	90.0	29	220	5.9	216
Mean	151.7	286.3	20.0	231.7	660	79.7	30	211	4.5	220
Std dev	10.3	27.2	1.0	5.0	48	9.0	3	12	2.2	88
Treatment, vegetated, surface										
OP1	128.0	258.0	19.0	217.0	624	71.0	30	200	5.5	228
OP2	157.0	321.0	20.0	254.0	692	84.0	29	248	6.0	166
OP3	142.0	309.0	19.0	242.0	643	76.0	33	224	9.1	287
Mean	142.3	296.0	19.3	237.7	653	77.0	31	224	6.9	227
Std dev	14.5	33.5	0.6	18.9	35	6.6	2	24	2.0	61
Control, unvegetated, surface										
OT1	5.2	11.5	6.7	31.9	15	15.0	15	66	7.3	216
OT2	5.8	11.1	6.8	36.0	15	14.0	14	68	10.0	226
Mean	5.5	11.3	6.8	34.0	15	14.5	15	67	8.7	221
Std dev	0.4	0.3	0.1	2.9	0	0.7	1	1	1.9	7
Treatment, unvegetated, surface										
OT1	42.0	129.0	9.9	301.0	43	51.0	17	123	34.0	293
OT2	47.0	147.0	10.0	338.0	52	57.0	17	135	30.3	308
OT3	41.0	133.0	8.6	299.0	41	53.0	16	146	14.0	255
Mean	43.3	136.3	9.5	312.7	45	53.7	17	135	26.1	285
Std dev	3.2	9.5	0.8	22.0	6	3.1	1	12	10.6	27
Treatment, vegeated, surface										
OT1	44.0	139.0	10.0	330.0	45	54.0	19	133	44.0	303
OT2	45.7	142.0	9.8	334.0	48	55.8	17	131	74.0	237
OT3	112.0	130.0	9.7	304.0	43	51.0	18	124	49.0	292
Mean	67.2	137.0	9.8	322.7	45	53.6	18	129	55.7	277
Std dev	38.8	6.2	0.2	16.3	3	2.4	1	5	16.1	35

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
TX1	30.6	86.0	17.0	131.0	540	42.0	57	132	7.5	47
TX2	31.6	83.0	18.1	96.0	528	46.8	54	140	7.9	112
Mean	31.1	84.5	17.6	113.5	534	44.4	55	136	7.7	80
Std dev	0.7	2.1	0.8	24.7	8	3.4	2	6	0.3	46
Treatment, unvegetated, surface										
TX1	166.0	936.0	42.0	687.0	1185	140.0	328	332	<1.0	53
TX2	159.0	910.0	50.0	687.0	1188	126.0	344	353	9.8	162
TX3	186.0	892.0	40.0	647.0	1219	119.0	325	347	<1.1	60
Mean	170.3	912.7	44.0	673.7	1197	128.3	332	344	<4.0	92
Std dev	14.0	22.1	5.3	23.1	19	10.7	10	11	5.1	61
Treatment, vegetated, surface										
TX1	181.0	899.0	45.0	661.0	1201	114.0	336	359	10.5	124
TX2	183.0	900.0	54.0	682.0	1275	128.0	346	371	13.0	157
TX3	172.8	924.0	48.0	705.0	1251	124.0	345	374	13.0	168
Mean	178.9	907.7	49.0	682.7	1242	122.0	342	368	12.2	150
Std dev	5.4	14.2	4.6	22.0	38	7.2	6	8	1.4	23
Control, unvegetated, surface										
WA1	23.6	34.8	27.3	49.0	8	38.0	62	114	5.3	1445
WA2	22.0	32.0	25.6	45.7	6	32.5	58	110	4.6	1268
Mean	22.8	33.4	26.5	47.4	7	35.3	60	112	5.0	1357
Std dev	1.1	2.0	1.2	2.3	1	3.9	3	3	0.5	125
Treatment, unvegetated, surface										
WA1	46.0	297.0	44.0	207.0	63	397.0	61	363	<1.1	1322
WA2	41.0	290.0	36.0	194.0	63	398.0	62	365	<1.1	1333
WA3	40.0	293.0	37.0	190.0	62	395.0	63	361	<1.3	1358
Mean	42.3	293.3	39.0	197.0	63	396.7	62	363	<1.2	1338
Std dev	3.2	3.5	4.4	8.9	1	1.5	1	2	0.1	18
Treatment, vegetated, surface										
WA1	39.0	286.0	37.0	190.0	59	368.0	62	345	<1.1	1224
WA2	37.0	289.0	36.0	178.0	61	333.0	61	332	<1.1	1181
WA3	36.6	307.0	37.0	180.0	58	333.0	63	434	<1.1	1250
Mean	37.5	294.0	36.7	182.7	59	344.7	62	370	<1.1	1218
Std dev	1.3	11.4	0.6	6.4	2	20.2	1	56	0.0	35

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, subsurface										
OP1	14.5	12.0	6.0	41.0	14	2.9	63	103	<1.4	1004
OP2	15.0	12.8	6.0	42.0	14	2.5	63	103	<1.4	1013
Mean	14.8	12.4	6.0	41.5	14	2.7	63	103	<1.4	1009
Std dev	0.4	0.6	0.0	0.7	0	0.3	0	0	0.0	6
Treatment, unvegetated, subsurface										
OT1	15.0	8.1	4.6	31.0	18	3.9	66	116	<1.1	1223
OP2	16.0	8.8	3.3	27.0	13	4.5	63	116	<1.1	1221
OP3	12.9	10.0	3.8	35.0	12	4.4	60	103	<1.1	1070
Mean	14.6	9.0	3.9	31.0	14	4.3	63	112	<1.1	1171
Std dev	1.6	1.0	0.7	4.0	3	0.3	3	8	0.0	88
Treatment, vegetated, subsurface										
OP1	16.0	6.1	3.4	28.0	11	8.4	62	119	<0.9	1224
OP2	16.0	7.2	3.1	23.0	10	6.7	64	116	7.6	1107
OP3	15.0	8.3	2.8	23.0	13	6.6	63	110	12.0	1139
Mean	15.7	7.2	3.1	24.7	11	7.2	63	115	<6.8	1157
Std dev	0.6	1.1	0.3	2.9	2	1.0	1	5	5.6	60
Control, unvegetated, subsurface										
OT1	14.0	11.1	5.4	39.0	15	2.2	68	106	1.6	1076
OT2	16.8	8.3	4.6	30.7	11	2.4	71	108	3.1	1223
Mean	15.4	9.7	5.0	34.9	13	2.3	70	107	2.4	1150
Std dev	2.0	2.0	0.6	5.9	3	0.1	2	1	1.1	104
Treatment, unvegetated, subsurface										
OT1	18.0	10.0	5.4	37.2	20	2.9	66	117	3.0	1071
OT2	15.0	6.8	2.9	26.7	18	2.9	64	110	<1.1	1096
OT3	15.0	7.2	3.4	27.0	16	2.4	65	107	<1.1	1040
Mean	16.0	8.0	3.9	30.3	18	2.7	65	111	<1.7	1069
Std dev	1.7	1.7	1.3	6.0	2	0.3	1	5	1.1	28
Treatment, vegetated, subsurface										
OT1	20.4	9.2	5.4	36.7	17	3.2	69	112	1.7	1048
OT2	20.0	8.2	6.6	40.0	21	3.7	67	119	5.3	1030
OT3	18.0	8.3	5.5	39.7	16	3.4	66	115	6.2	1080
Mean	19.5	8.6	5.8	38.8	18	3.4	67	115	4.4	1053
Std dev	1.3	0.6	0.7	1.8	3	0.3	1	4	2.4	25

TABLE B-1. (CONTINUED) TOTAL EXTRACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, subsurface										
TX1	15.0	11.0	5.8	41.8	<12	2.6	65	108	<1.4	1215
TX2	15.0	15.0	5.4	42.0	13	3.1	67	106	<1.4	1142
Mean	15.0	13.0	5.6	41.9	<13	2.9	66	107	<1.4	1179
Std dev	0.0	2.8	0.3	0.1	1	0.4	1	.1	0.0	52
Treatment, unvegetated, subsurface										
TX1	12.0	14.0	4.9	41.0	21	4.6	62	103	<1.2	1142
TX2	7.3	9.3	3.8	32.0	11	3.6	62	103	<1.2	1054
TX3	6.4	9.6	3.9	33.0	13	3.3	60	102	<1.1	958
Mean	8.6	11.0	4.2	35.3	15	3.8	61	103	<1.2	1051
Std dev	3.0	2.6	0.6	4.9	5	0.7	1	1	0.1	92
Treatment, vegetated, subsurface										
TX1	12.0	8.1	5.1	31.0	15	5.2	62	115	1.9	887
TX2	10.8	8.1	6.7	36.7	<15	5.9	66	120	<1.3	1228
TX3	8.8	7.8	4.4	25.8	14	6.4	63	110	<1.1	889
Mean	10.5	8.0	5.4	31.2	<15	5.8	64	115	<1.4	1001
Std dev	1.6	0.2	1.2	5.5	1	0.6	2	5	0.4	196
Control, unvegetated, subsurface										
WA1	17.5	6.0	3.4	23.0	14	2.8	65	106	<1.0	1081
WA2	15.4	7.1	3.7	31.0	16	2.2	67	110	1.0	1039
Mean	16.5	6.6	3.6	27.0	15	2.5	66	108	<1.0	1060
Std dev	1.5	0.8	0.2	5.7	1	0.4	1	3	.0	30
Treatment, unvegetated, subsurface										
WA1	12.0	13.0	5.7	40.0	17	7.8	61	101	<1.2	1134
WA2										
WA3	12.0	11.0	4.7	41.0	15	7.3	61	106	<1.2	1061
Mean	12.0	12.0	5.2	40.5	16	7.6	61	104	<1.2	1098
Std dev	0.0	1.4	0.7	0.7	1	0.4	0	4	0.0	52
Treatment, vegetated, subsurface										
WA1	7.1	10.7	6.0	42.5	13	23.0	66	95	<1.2	1003
WA2	6.1	12.0	5.0	40.0	14	11.7	64	102	<1.2	1002
WA3	5.8	10.0	4.9	41.0	12	24.0	66	101	<1.1	1015
Mean	6.3	10.9	5.3	41.2	13	19.6	65	99	<1.2	1007
Std dev	0.7	1.0	0.6	1.3	1	6.8	1	4	0.1	7

TABLE B-2. SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, surface										
OP2	16.0	74.0	33.0	12.0	14.0	1.20	<0.05	<0.05	29.0	<0.02
OP1	13.0	55.0	16.0	7.4	14.0	0.72	<0.05	<0.05	28.0	<0.02
Mean	14.5	64.5	24.5	9.7	14.0	0.96	<0.05	<0.05	28.5	<0.02
Std dev	2.1	13.4	12.0	3.3	0.0	0.34	0.00	0.00	0.7	0.00
Treatment, unvegetated, surface										
OP1	118.0	36.0	831.0	100.0	<0.5	6.90	<0.05	<0.05	<0.5	<0.02
OP2	101.0	34.0	779.0	98.0	8.3	11.00	<0.05	<0.05	17.0	<0.02
OP3	68.0	22.0	410.0	55.0	1.0	5.00	<0.05	<0.05	2.0	<0.02
Mean	95.7	30.7	673.3	84.3	<3.3	7.63	<0.05	<0.05	<6.5	<0.02
Std dev	25.4	7.6	229.5	25.4	4.4	3.07	0.00	0.00	9.1	0.00
Treatment, vegetated, surface										
OP2	48.0	27.0	453.0	51.0	6.3	1.20	<0.05	<0.05	12.0	<0.02
OP1	38.0	21.0	251.0	28.0	3.3	0.48	<0.05	<0.05	6.7	<0.02
OP3	45.0	23.0	376.0	40.0	3.6	2.30	<0.05	<0.05	7.1	<0.02
Mean	43.7	23.7	360.0	39.7	4.4	1.33	<0.05	<0.05	8.6	<0.02
Std dev	5.1	3.1	101.9	11.5	1.7	0.92	0.00	0.00	3.0	0.00
Control, unvegetated, surface										
OT2	11.8	23.0	39.0	6.1	19.0	0.38	<0.05	<0.05	31.0	<0.02
OT1	4.1	14.0	10.0	4.9	16.0	0.28	<0.05	<0.05	23.2	<0.02
Mean	8.0	18.5	24.5	5.5	17.5	0.33	<0.05	<0.05	27.1	<0.02
Std dev	5.4	6.4	20.5	0.8	2.1	0.07	0.00	0.00	5.5	0.00
Treatment, unvegetated, surface										
OT2	18.0	25.0	102.0	12.0	12.0	0.89	<0.05	<0.05	17.0	<0.02
OT3	22.0	23.0	83.0	9.4	4.0	0.56	<0.05	<0.05	5.8	<0.02
OT1	14.0	28.0	108.0	15.0	42.0	1.60	<0.05	<0.05	68.0	<0.02
Mean	18.0	25.3	97.7	12.1	19.3	1.02	<0.05	<0.05	30.3	<0.02
Std dev	4.0	2.5	13.1	2.8	20.0	0.53	0.00	0.00	33.2	0.00
Treatment, vegetated, surface										
OT2	16.0	20.0	68.0	7.4	5.6	0.34	<0.05	<0.05	7.4	<0.02
OT1	11.0	14.0	69.0	6.5	5.1	0.23	<0.05	<0.05	7.7	<0.02
OT3	11.0	20.0	82.0	8.3	6.7	0.26	<0.05	<0.05	11.0	<0.02
Mean	12.7	18.0	73.0	7.4	5.8	0.28	<0.05	<0.05	8.7	<0.02
Std dev	2.9	3.5	7.8	0.9	0.8	0.06	0.00	0.00	2.0	0.00

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, surface										
TX2	28.0	14.0	186.0	22.0	1.2	<0.05	<0.05	0.63	1.5	<0.02
TX1	29.0	18.0	233.0	27.0	11.0	0.15	<0.05	0.62	23.0	<0.02
Mean	28.5	16.0	209.5	24.5	6.1	<0.10	<0.05	0.63	12.3	<0.02
Std dev	0.7	2.8	33.2	3.5	6.9	0.07	0.00	0.01	15.2	0.00
Treatment, unvegetated, surface										
TX3	410.0	17.0	2810.0	485.0	3.2	20.00	0.41	0.63	6.3	<0.02
TX2	373.0	18.0	2763.0	453.0	<0.5	12.00	0.16	0.78	<0.5	<0.02
TX1	454.0	22.0	3082.0	520.0	<0.6	21.00	0.44	0.72	<0.5	<0.02
Mean	412.3	19.0	2885.0	486.0	<1.4	17.67	0.34	0.71	<2.4	<0.02
Std dev	40.6	2.6	172.2	33.5	1.5	4.93	0.15	0.08	3.3	0.00
Treatment, vegetated, surface										
TX2	285.0	25.0	3178.0	435.0	10.0	1.90	0.04	0.89	18.0	<0.01
TX1	181.0	17.0	2857.0	360.0	<0.2	3.20	0.04	0.78	<0.2	<0.01
TX3	144.0	23.0	2284.0	291.0	3.0	1.90	<0.03	0.57	5.3	<0.01
Mean	203.3	21.7	2773.0	362.0	<4.4	2.33	<0.04	0.75	<7.8	<0.01
Std dev	73.1	4.2	452.9	72.0	5.0	0.75	0.01	0.16	9.2	0.00
Control, unvegetated, surface										
WA2	15.0	5.0	20.0	7.5	14.0	0.54	<0.05	<0.05	17.6	<0.02
WA1	17.0	8.0	17.0	7.2	21.0	0.48	<0.05	<0.05	26.0	<0.02
Mean	16.0	6.5	18.5	7.4	17.5	0.51	<0.05	<0.05	21.8	<0.02
Std dev	1.4	2.1	2.1	0.2	4.9	0.04	0.00	0.00	5.9	0.00
Treatment, unvegetated, surface										
WA1	112.0	68.0	730.0	193.0	5.1	27.00	0.45	<0.05	45.0	0.02
WA2	122.0	73.0	1042.0	248.0	6.4	35.00	0.61	<0.05	54.0	0.03
WA3	117.0	70.0	900.0	218.0	5.9	30.00	0.51	<0.05	47.0	0.02
Mean	117.0	70.3	890.7	219.7	5.8	30.67	0.52	<0.05	48.7	0.02
Std dev	5.0	2.5	156.2	27.5	0.7	4.04	0.08	0.00	4.7	0.01
Treatment, vegetated, surface										
WA2	51.0	52.0	313.0	85.0	2.1	12.00	0.23	<0.05	26.7	<0.02
WA1	74.0	66.0	486.0	134.0	3.7	19.00	0.33	<0.05	38.0	0.02
WA3	39.0	49.0	259.0	61.0	1.5	8.50	0.16	<0.05	22.0	<0.02
Mean	54.7	55.7	352.7	93.3	2.4	13.17	0.24	<0.05	28.9	<0.02
Std dev	17.8	9.1	118.6	37.2	1.1	5.35	0.09	0.00	8.2	0.00

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, subsurface										
OP2	9.3	14.0	3.2	6.5	<0.5	1.00	<0.05	<0.05	<0.5	<0.02
OP1	7.8	7.0	<0.5	1.4	<0.5	0.20	<0.05	<0.05	<0.5	<0.02
Mean	8.6	10.5	<1.9	4.0	<0.5	0.60	<0.05	<0.05	<0.5	<0.02
Std dev	1.1	4.9	1.9	3.6	0.0	0.57	0.00	0.00	0.0	0.00
Treatment, unvegetated, subsurface										
OP2	24.0	7.8	14.0	5.5	<0.5	0.94	<0.05	<0.05	<0.5	<0.02
OP1	42.0	15.0	41.0	16.0	<0.5	2.60	<0.05	<0.05	<0.5	<0.02
OP3	32.0	8.7	18.0	6.2	<0.5	1.00	<0.05	<0.05	<0.5	<0.02
Mean	32.7	10.5	24.3	9.2	<0.5	1.51	<0.05	<0.05	<0.5	<0.02
Std dev	9.0	3.9	14.6	5.9	0.0	0.94	0.00	0.00	0.0	0.00
Treatment, vegetated, subsurface										
OP1	25.0	6.2	45.0	8.7	<0.5	1.20	<0.05	<0.05	0.8	<0.02
OP2	31.0	8.1	85.0	23.0	<0.5	3.40	<0.05	<0.05	<0.5	<0.02
OP3	31.0	9.9	83.0	20.0	<0.5	5.40	0.06	<0.05	0.6	<0.02
Mean	29.0	8.1	71.0	17.2	<0.5	3.33	<0.05	<0.05	<0.6	0.02
Std dev	3.5	1.9	22.5	7.5	0.0	2.10	0.01	0.00	0.1	0.00
Control, unvegetated, subsurface										
OT2	8.5	4.7	4.0	1.5	<0.5	0.25	<0.05	<0.05	<0.5	<0.02
OT1	3.7	3.1	<0.5	<0.5	<0.5	<0.05	<0.05	<0.05	<0.5	<0.02
Mean	6.1	3.9	<2.3	<1.0	<0.5	<0.15	<0.05	<0.05	<0.5	<0.02
Std dev	3.4	1.1	2.5	0.7	0.0	0.14	0.00	0.00	0.0	0.00
Treatment, unvegetated, subsurface										
OT2	16.0	12.0	19.0	6.5	<0.5	1.00	<0.05	<0.05	<0.5	<0.02
OT3	17.0	9.3	8.6	3.2	<0.5	0.53	<0.05	<0.05	<0.5	<0.02
OT1	14.0	10.0	12.0	4.7	<0.5	0.72	<0.05	<0.05	<0.5	<0.02
Mean	15.7	10.4	13.2	4.8	<0.5	0.75	<0.05	<0.05	<0.5	<0.02
Std dev	1.5	1.4	5.3	1.7	0.0	0.24	0.00	0.00	0.0	0.00
Treatment, vegetated, subsurface										
OT2	19.0	7.7	25.0	8.4	<0.5	1.60	<0.05	<0.05	<0.5	<0.05
OT3	17.0	8.3	18.0	7.0	<0.5	1.30	<0.05	<0.05	<0.5	<0.02
OT1	16.0	8.0	12.0	4.0	<0.5	0.64	<0.05	<0.05	<0.5	<0.02
Mean	17.3	8.0	18.3	6.5	<0.5	1.18	<0.05	<0.05	<0.5	0.03
Std dev	1.5	0.3	6.5	2.2	0.0	0.49	0.00	0.00	0.0	0.02

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, subsurface										
TX2	11.0	4.5	2.2	1.8	<0.5	0.23	<0.05	<0.05	<0.5	<0.02
TX1	11.0	5.2	<0.6	1.7	<0.5	0.30	<0.05	<0.05	<0.5	<0.02
Mean	11.0	4.9	<1.4	1.8	<0.5	0.27	<0.05	<0.05	<0.5	<0.02
Std dev	0.0	0.5	1.2	0.1	0.0	0.05	0.00	0.00	0.0	0.00
Treatment, unvegetated, subsurface										
TX1	127.0	13.0	160.0	48.0	<0.5	5.80	0.09	<0.05	<0.5	<0.02
TX2	119.0	11.0	123.0	45.0	<0.5	4.90	0.08	<0.05	<0.5	<0.02
TX3	101.0	11.0	57.0	23.0	<0.5	4.10	0.07	<0.05	<0.5	<0.02
Mean	115.7	11.7	113.3	38.7	<0.5	4.93	0.08	<0.05	<0.5	<0.02
Std dev	13.3	1.2	52.2	13.7	0.0	0.85	0.01	0.00	0.0	0.00
Treatment, vegetated, subsurface										
TX2	93.0	6.8	110.0	46.0	<0.1	1.90	<0.03	<0.01	<0.2	<0.01
TX1	100.0	6.2	116.0	48.0	<0.1	2.30	0.04	<0.01	<0.2	<0.01
TX3	83.0	5.7	171.0	49.0	<0.5	2.10	<0.05	<0.05	<0.5	<0.02
Mean	92.0	6.2	132.3	47.7	<0.2	2.10	<0.04	<0.02	<0.3	<0.01
Std dev	8.5	0.6	33.6	1.5	0.3	0.20	0.01	0.02	0.2	0.00
Control, unvegetated, subsurface										
WA2	5.0	3.7	1.6	0.9	<0.5	0.11	<0.05	<0.05	<0.5	<0.02
WA1	5.7	2.8	1.8	0.9	<0.5	0.09	<0.05	<0.05	<0.5	<0.02
Mean	5.4	3.3	1.7	0.9	<0.5	0.10	<0.05	<0.05	<0.5	<0.02
Std dev	0.5	0.6	0.1	0.0	0.0	0.01	0.00	0.00	0.0	0.00
Treatment, unvegetated, subsurface										
WA3	34.0	21.0	29.0	18.0	<0.5	4.00	0.09	<0.05	<0.5	<0.02
WA2	32.0	14.0	7.6	4.5	<0.5	0.89	<0.05	<0.05	<0.5	<0.02
WA1	38.0	17.0	14.0	10.0	<0.5	2.20	<0.05	<0.05	<0.5	<0.02
Mean	34.7	17.3	16.9	10.8	<0.5	2.36	<0.06	<0.05	<0.5	<0.02
Std dev	3.1	3.5	11.0	6.8	0.0	1.56	0.02	0.00	0.0	0.00
Treatment, vegetated, subsurface										
WA1	37.0	32.0	61.0	24.0	<0.5	9.70	0.23	<0.05	1.2	<0.02
WA3	24.0	26.0	38.0	15.0	<0.5	5.30	0.15	<0.05	1.6	<0.02
WA2	46.0	33.0	123.0	51.0	<0.5	13.00	0.29	<0.05	1.7	<0.02
Mean	35.7	30.3	74.0	30.0	<0.5	9.33	0.22	<0.05	1.5	<0.02
Std dev	11.1	3.8	44.0	18.7	0.0	3.86	0.07	0.00	0.3	0.00

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
OP2	<0.05	<0.05	<0.05	<0.05	<0.1	0.23	<0.05	0.32	0.14	0.69
OP1	<0.05	<0.05	<0.05	<0.05	<0.1	0.12	<0.05	0.21	0.09	0.67
Mean	<0.05	<0.05	<0.05	<0.05	<0.1	0.18	<0.05	0.27	0.12	0.68
Std dev	0.00	0.00	0.00	0.00	0.0	0.08	0.00	0.08	0.04	0.01
Treatment, unvegetated, surface										
OP1	0.47	<0.05	0.33	0.91	0.1	6.50	<0.05	0.28	0.26	<0.50
OP2	0.56	0.05	0.30	1.10	0.3	6.00	<0.05	0.39	0.23	0.55
OP3	0.29	<0.05	0.45	1.50	<0.1	3.30	<0.05	0.24	0.17	<0.50
Mean	0.44	<0.05	0.36	1.17	<0.2	5.27	<0.05	0.30	0.22	<0.52
Std dev	0.14	0.00	0.08	0.30	0.1	1.72	0.00	0.08	0.05	0.03
Treatment, vegetated, surface										
OP2	0.45	<0.05	0.21	1.60	0.2	3.80	<0.05	0.30	0.13	0.50
OP1	0.30	<0.05	0.11	1.20	<0.1	2.10	<0.05	0.18	0.12	<0.50
OP3	0.48	<0.05	0.21	1.50	0.1	3.20	<0.05	0.27	0.13	<0.50
Mean	0.41	<0.05	0.18	1.43	<0.1	3.03	<0.05	0.25	0.13	<0.50
Std dev	0.10	0.00	0.06	0.21	0.1	0.86	0.00	0.06	0.01	0.00
Control, unvegetated, surface										
OT2	0.62	<0.05	0.55	0.76	0.2	0.07	0.05	0.19	<0.05	1.05
OT1	0.28	<0.05	<0.05	<0.08	<0.1	<0.05	<0.05	0.13	0.05	0.65
Mean	0.45	<0.05	<0.30	<0.42	<0.1	<0.06	<0.05	0.16	<0.05	0.85
Std dev	0.24	0.00	0.35	0.48	0.0	0.01	0.00	0.04	0.00	0.28
Treatment, unvegetated, surface										
OT2	0.51	0.15	0.11	1.10	0.1	0.37	<0.05	0.26	0.08	<0.50
OT3	0.44	0.06	0.11	0.89	<0.1	0.31	<0.05	0.16	0.05	<0.50
OT1	0.65	0.49	0.23	2.60	0.4	0.43	0.12	0.55	<0.05	2.30
Mean	0.53	0.23	0.15	1.53	<0.2	0.37	<0.07	0.32	<0.06	<1.10
Std dev	0.11	0.23	0.07	0.93	0.2	0.06	0.04	0.20	0.02	1.04
Treatment, vegetated, surface										
OT2	0.45	0.08	0.65	1.60	<0.1	0.29	<0.05	0.14	<0.05	<0.50
OT1	0.30	<0.05	0.39	0.80	<0.1	0.28	<0.05	0.13	0.09	<0.50
OT3	0.34	0.05	0.19	1.00	<0.1	0.35	<0.05	0.13	<0.05	<0.50
Mean	0.36	<0.06	0.41	1.13	<0.1	0.31	<0.05	0.13	<0.06	<0.50
Std dev	0.08	0.02	0.23	0.42	0.0	0.04	0.00	0.01	0.02	0.00

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, surface										
TX2	0.10	<0.05	<0.05	<0.05	<0.1	0.72	<0.05	0.12	0.08	<0.50
TX1	0.25	<0.05	0.19	0.82	0.3	0.89	0.06	0.23	0.08	1.40
Mean	0.18	<0.05	<0.12	<0.44	<0.2	0.81	<0.06	0.18	0.08	<0.95
Std dev	0.11	0.00	0.10	0.54	0.1	0.12	0.01	0.08	0.00	0.64
Treatment, unvegetated, surface										
TX3	0.52	0.27	0.66	5.70	0.1	7.20	0.26	0.20	0.14	<0.50
TX2	0.48	0.12	0.39	2.30	<0.1	6.90	0.19	0.14	0.08	<0.50
TX1	0.61	0.14	0.80	6.10	<0.1	8.20	0.20	0.16	0.08	<0.50
Mean	0.54	0.18	0.62	4.70	<0.1	7.43	0.22	0.17	0.10	<0.50
Std dev	0.07	0.08	0.21	2.09	0.0	0.68	0.04	0.03	0.03	0.00
Treatment, vegetated, surface										
TX2	0.58	0.52	0.25	0.61	0.6	7.90	0.33	0.35	0.03	0.96
TX1	0.41	0.07	0.18	1.20	<0.1	7.10	0.12	0.15	<0.03	<0.05
TX3	0.37	0.19	0.31	2.50	0.2	5.80	0.14	0.23	0.04	0.29
Mean	0.45	0.26	0.25	1.44	<0.3	6.93	0.20	0.24	<0.03	<0.43
Std dev	0.11	0.23	0.07	0.97	0.3	1.06	0.12	0.10	0.00	0.47
Control, unvegetated, surface										
WA2	0.11	<0.05	0.19	0.51	<0.1	0.15	<0.05	0.19	0.05	1.20
WA1	0.13	<0.05	0.37	0.89	0.1	0.12	0.06	0.20	0.06	1.70
Mean	0.12	<0.05	0.28	0.70	<0.1	0.14	<0.06	0.20	0.06	1.45
Std dev	0.01	0.00	0.13	0.27	0.0	0.02	0.01	0.01	0.01	0.35
Treatment, unvegetated, surface										
WA1	0.28	0.11	0.85	8.60	<0.1	16.00	<0.05	0.50	0.06	<0.50
WA2	0.25	0.13	0.76	11.00	0.1	20.00	<0.05	0.45	<0.05	<0.50
WA3	0.23	0.11	0.62	8.90	<0.1	18.00	<0.05	0.47	0.06	<0.50
Mean	0.25	0.12	0.74	9.50	<0.1	18.00	<0.05	0.47	<0.06	<0.50
Std dev	0.03	0.01	0.12	1.31	0.0	2.00	0.00	0.03	0.01	0.00
Treatment, vegetated, surface										
WA2	0.17	0.06	0.36	5.10	<0.1	15.00	<0.05	0.46	0.06	<0.50
WA1	0.25	0.09	0.48	7.10	<0.1	15.00	<0.05	0.50	<0.05	<0.50
WA3	0.24	0.06	0.41	8.00	<0.1	18.00	<0.05	0.58	0.12	<0.50
Mean	0.22	0.07	0.42	6.73	<0.1	16.00	<0.05	0.51	<0.08	<0.50
Std dev	0.04	0.02	0.06	1.48	0.0	1.73	0.00	0.06	0.04	0.00

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, subsurface										
OP2	0.07	<0.05	0.12	0.32	<0.1	<0.05	<0.05	0.49	<0.05	<0.05
OP1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.09	<0.05	<0.50
Mean	<0.06	<0.05	<0.09	<0.19	<0.1	<0.05	<0.05	0.29	<0.05	<0.28
Std dev	0.01	0.00	0.05	0.19	0.0	0.00	0.00	0.28	0.00	0.32
Treatment, unvegetated, subsurface										
OP2	<0.05	<0.05	0.11	0.59	<0.1	0.05	<0.05	0.16	0.08	<0.50
OP1	0.07	<0.05	0.10	0.43	<0.1	0.14	<0.05	0.52	0.09	<0.50
OP3	<0.05	<0.05	0.05	0.47	<0.1	0.06	<0.05	0.15	<0.05	<0.50
Mean	<0.06	<0.05	0.09	0.50	<0.1	0.08	<0.05	0.28	<0.07	<0.50
Std dev	0.01	0.00	0.03	0.08	0.0	0.05	0.00	0.21	0.02	0.00
Treatment, vegetated, subsurface										
OP1	<0.05	<0.05	0.06	0.25	<0.1	0.14	<0.05	0.06	<0.05	<0.50
OP2	0.07	<0.05	<0.05	0.32	<0.1	0.18	<0.05	0.06	0.06	<0.50
OP3	<0.05	<0.05	<0.05	0.38	<0.1	0.21	<0.05	0.07	<0.05	<0.50
Mean	<0.06	<0.05	<0.05	0.32	<0.1	0.18	<0.05	0.06	<0.05	<0.50
Std dev	0.01	0.00	0.01	0.07	0.0	0.04	0.00	0.01	0.01	0.00
Control, unvegetated, subsurface										
OT2	<0.05	<0.05	<0.05	0.16	<0.1	<0.05	<0.05	0.17	<0.05	<0.50
OT1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.05	<0.50
Mean	<0.05	<0.05	<0.05	<0.11	<0.1	<0.05	<0.05	<0.11	<0.05	<0.50
Std dev	0.00	0.00	0.00	0.08	0.0	0.00	0.00	0.08	0.00	0.00
Treatment, unvegetated, subsurface										
OT2	0.07	<0.05	0.06	0.39	<0.1	0.06	<0.05	0.46	<0.05	<0.50
OT3	<0.05	<0.05	<0.05	0.16	<0.1	<0.05	<0.05	0.23	<0.05	<0.50
OT1	0.06	<0.05	0.08	0.43	<0.1	<0.05	<0.05	0.33	<0.05	<0.50
Mean	<0.06	<0.05	<0.06	0.33	<0.1	<0.05	<0.05	0.34	<0.05	<0.50
Std dev	0.01	0.00	0.02	0.15	0.0	0.01	0.00	0.12	0.00	0.00
Treatment, vegetated, subsurface										
OT2	<0.05	0.11	0.25	<0.10	<0.1	<0.05	0.05	0.10	<0.05	<0.05
OT3	<0.05	<0.05	0.07	0.32	<0.1	<0.05	<0.05	0.14	<0.05	<0.50
OT1	<0.05	<0.05	0.08	0.45	<0.1	<0.05	<0.05	0.14	0.11	<0.50
Mean	<0.05	<0.07	0.13	<0.29	<0.1	<0.05	<0.05	0.13	<0.07	<0.35
Std dev	0.00	0.03	0.10	0.18	0.0	0.00	0.00	0.02	0.03	0.26

TABLE B-2. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, GREENHOUSE STUDY, 6/84.

Location and Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, subsurface										
TX2	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.09	0.06	<0.50
TX1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.12	0.05	<0.50
Mean	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	0.11	0.06	<0.50
Std dev	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.02	0.01	0.00
Treatment, unvegetated, subsurface										
TX1	0.05	<0.05	0.14	0.83	<0.1	0.24	<0.05	0.07	<0.05	<0.50
TX2	<0.05	<0.05	0.05	0.56	<0.1	0.19	<0.05	0.08	<0.05	<0.50
TX3	<0.05	<0.05	0.08	0.75	<0.1	0.08	<0.05	0.09	0.08	<0.50
Mean	<0.05	<0.05	0.09	0.71	<0.1	0.17	<0.05	0.08	<0.06	<0.50
Std dev	0.00	0.00	0.05	0.14	0.0	0.08	0.00	0.01	0.02	0.00
Treatment, vegetated, subsurface										
TX2	<0.02	<0.01	0.63	1.04	<0.1	0.18	<0.07	0.09	<0.03	<0.04
TX1	<0.02	<0.01	0.05	0.57	<0.1	0.17	<0.07	0.06	<0.03	<0.05
TX3	0.06	<0.05	0.99	0.73	<0.1	0.27	<0.05	0.05	0.11	<0.50
Mean	<0.03	<0.02	0.56	0.78	<0.1	0.21	<0.06	0.07	<0.06	<0.20
Std dev	0.02	0.02	0.47	0.24	0.0	0.06	0.01	0.02	0.05	0.26
Control, unvegetated, subsurface										
WA2	<0.05	<0.05	<0.05	0.12	<0.1	<0.05	<0.05	0.06	0.06	<0.50
WA1	<0.05	<0.05	<0.05	0.11	<0.1	<0.05	<0.05	<0.05	0.05	<0.50
Mean	<0.05	<0.05	<0.05	0.12	<0.1	<0.05	<0.05	<0.06	0.06	<0.50
Std dev	0.00	0.00	0.00	0.01	0.0	0.00	0.00	0.01	0.01	0.00
Treatment, unvegetated, subsurface										
WA3	<0.05	<0.05	0.06	0.46	0.1	0.31	<0.05	0.50	0.08	<0.50
WA2	<0.05	<0.05	<0.05	0.57	<0.1	0.07	<0.05	0.17	0.09	<0.50
WA1	<0.05	<0.05	0.09	0.42	<0.1	0.16	<0.05	0.20	0.12	<0.50
Mean	<0.05	<0.05	<0.07	0.48	<0.1	0.18	<0.05	0.29	0.10	<0.50
Std dev	0.00	0.00	0.02	0.08	0.0	0.12	0.00	0.18	0.02	0.00
Treatment, vegetated, subsurface										
WA1	0.06	<0.05	0.09	1.10	<0.1	1.70	<0.05	0.24	0.18	<0.50
WA3	0.05	<0.05	0.27	0.94	<0.1	1.20	<0.05	0.17	0.08	<0.50
WA2	0.12	<0.05	0.09	3.30	<0.1	1.10	<0.05	0.24	0.13	<0.50
Mean	0.08	<0.05	0.15	1.78	<0.1	1.33	<0.05	0.22	0.13	<0.50
Std dev	0.04	0.00	0.10	1.32	0.0	0.32	0.00	0.04	0.05	0.00

TABLE B-3. TOTAL EXTACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, 0-25 cm depth										
1	65	1765	2367	2389	7984	203	3.7	<0.9	7968	<0.26
2	54	1440	2408	2346	7832	231	3.7	<0.9	7108	<0.27
3	72	1572	4385	2359	7795	189	3.5	<1.0	7616	<0.29
Mean	64	1592	3053	2365	7870	208	3.6	<0.9	7564	<0.27
Std dev	9	163	1153	22	100	21	0.1	0.1	432	0.02
Treatment, unvegetated, 0-25 cm depth										
1	192	1908	21001	2306	7727	165	3.6	1.0	8997	0.41
2	169	2204	22963	2338	7783	163	3.3	1.1	9312	0.50
3	174	1885	20479	2283	7715	170	3.5	1.0	8996	0.38
Mean	178	1999	21481	2309	7742	166	3.5	1.0	9102	0.43
Std dev	12	178	1310	28	36	4	0.2	0.1	182	0.06
Treatment, vegetated, 0-25 cm depth										
1	273	2404	1886	2413	7772	149	2.9	1.5	9405	0.39
2	149	1846	18170	2274	7506	158	3.3	1.0	8126	0.37
3	211	2141	21741	2385	7906	152	2.9	1.0	9025	0.51
Mean	211	2130	13932	2357	7728	153	3.0	1.2	8852	0.42
Std dev	62	279	10584	74	204	5	0.2	0.3	657	0.08
Control, unvegetated, 25-50 cm depth										
1	51	1119	1289	2183	6071	100	2.2	<0.9	5691	<0.27
2	69	1858	1999	2497	8405	233	3.7	<0.9	8325	<0.26
3	86	1688	1833	3244	9512	160	4.1	<1.0	9059	<0.28
Mean	69	1555	1707	2641	7996	164	3.3	<0.9	7692	<0.27
Std dev	18	387	371	545	1757	67	1.0	.0	1771	0.01
Treatment, unvegetated, 25-50 cm depth										
1	72	1517	1644	2837	8179	156	3.4	<1.0	7797	<0.30
2	65	1107	1290	2456	6345	174	2.8	<1.0	5338	<0.28
3	154	2148	1872	3593	10609	197	4.8	<1.0	10996	<0.28
Mean	97	1591	1602	2962	8378	176	3.7	<1.0	8044	<0.29
Std dev	49	524	293	579	2139	21	1.0	.0	2837	0.01
Treatment, vegetated, 25-50 cm depth										
1	65	1240	1438	2792	7074	156	2.8	<0.9	6240	<0.28
2	522	1484	1285	3007	7192	133	2.9	<1.0	6628	<0.28
3	65	1202	1598	2425	6704	162	2.8	<0.9	5881	<0.26
Mean	217	1309	1440	2741	6990	150	2.8	<0.9	6250	<0.27
Std dev	264	153	157	294	255	15	0.1	.0	374	0.01

TABLE B-3. (CONTINUED) TOTAL EXTACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, 50-75 cm depth										
1	57	1340	2145	2379	7064	133	2.8	<0.9	6792	<0.30
2	66	1653	2287	2550	8705	237	4.0	<0.9	8564	<0.28
3	55	1248	1423	2441	6971	121	2.9	<0.9	6278	<0.27
Mean	59	1414	1952	2457	7580	164	3.2	<0.9	7211	<0.28
Std dev	6	212	463	87	975	64	0.7	0.0		0.02
Treatment, unvegetated, 50-75 cm depth										
1	92	1869	1487	3383	8941	145	3.4	<1.0	9341	<0.29
2	75	1460	1263	2954	7390	100	2.6	<0.9	6842	<0.28
3	66	1101	1128	2475	6246	105	2.8	<1.0	5649	<0.29
Mean	78	1477	1293	2937	7526	117	2.9	<1.0	7277	<0.29
Std dev	13	384	181	454	1353	25	0.4	0.0	1884	0.01
Treatment, vegetated, 50-75 cm depth										
1	350	1252	1468	2759	6362	116	2.5	<0.9	5704	<0.27
2	61	1230	1497	2813	6807	115	2.7	<1.0	6219	<0.29
3	72	1377	1390	3139	7297	130	2.5	<1.0	6651	<0.28
Mean	161	1286	1452	2904	6822	120	2.6	<0.9	6191	<0.28
Std dev	164	79	55	206	468	8	0.1	0.0	474	0.01

TABLE B-3. (CONTINUED) TOTAL EXTACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 0-25 cm depth										
1	6.8	13.0	7.2	38.0	19	15.0	16	72	9.2	266
2	7.3	14.0	7.4	41.0	23	15.0	14	74	8.9	194
3	5.9	12.0	6.8	32.0	13	15.0	16	65	14.0	246
Mean	6.7	13.0	7.1	37.0	18	15.0	15	70	10.7	235
Std dev	0.7	1.0	0.3	4.6	5	0.0	1	5	2.9	37
Treatment, unvegetated, 0-25 cm depth										
1	52.0	135.0	8.6	330.0	41	55.0	16	134	39.0	266
2	52.0	159.0	8.8	364.0	49	62.0	16	144	14.0	214
3	50.0	127.0	8.4	301.0	41	54.0	16	131	22.0	261
Mean	51.3	140.3	8.6	331.7	44	57.0	16	136	25.0	247
Std dev	1.2	16.7	0.2	31.5	5	4.4	0	7	12.8	29
Treatment, vegetated, 0-25 cm depth										
1	59.0	150.0	8.7	344.0	50	59.0	17	136	31.0	259
2	46.0	147.0	8.7	335.0	45	54.0	15	130	13.0	207
3	54.0	159.0	9.5	343.0	51	70.0	17	150	18.0	234
Mean	53.0	152.0	9.0	340.7	49	61.0	16	139	20.7	233
Std dev	6.6	6.2	0.5	4.9	3	8.2	1	10	9.3	26
Control, unvegetated, 25-50 cm depth										
1	2.9	8.0	5.7	12.0	3	10.0	12	35	5.8	189
2	6.3	11.0	7.8	31.0	12	14.0	16	73	9.2	264
3	5.8	12.0	9.1	26.0	6	15.0	18	68	14.0	237
Mean	5.0	10.3	7.5	23.0	7	13.0	15	59	9.7	230
Std dev	1.8	2.1	1.7	9.8	5	2.6	3	21	4.1	38
Treatment, unvegetated, 25-50 cm depth										
1	7.1	11.0	7.9	24.0	6	15.0	15	62	6.2	193
2	7.0	7.6	6.4	20.0	6	12.0	11	46	4.7	98
3	8.8	14.0	10.0	28.0	6	21.0	22	79	41.0	329
Mean	7.6	10.9	8.1	24.0	6	16.0	16	62	17.3	207
Std dev	1.0	3.2	1.8	4.0	0	4.6	6	17	20.5	116
Treatment, vegetated, 25-50 cm depth										
1	6.5	8.5	7.5	17.0	5	14.0	12	47	7.3	132
2	8.5	8.4	7.3	18.0	4	13.0	12	50	7.0	118
3	7.5	8.9	6.8	25.0	7	16.0	12	47	5.3	139
Mean	7.5	8.6	7.2	20.0	6	14.3	12	48	6.5	130
Std dev	1.0	0.3	0.4	4.4	1	1.5	0	2	1.1	11

TABLE B-3. (CONTINUED) TOTAL EXTACTABLE METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 50-75 cm depth										
1	4.7	10.0	6.1	19.0	6	14.0	15	48	10.0	251
2	6.3	12.0	8.2	27.0	7	16.0	17	82	8.1	257
3	3.9	8.7	6.7	16.0	5	12.0	13	47	13.0	194
Mean	5.0	10.2	7.0	20.7	6	14.0	15	59	10.4	234
Std dev	1.2	1.7	1.1	5.7	1	2.0	2	20	2.5	35
Treatment, unvegetated, 50-75 cm depth										
1	6.1	12.0	8.3	18.0	4	16.0	18	54	10.0	268
2	6.3	8.7	6.8	17.0	5	11.0	13	41	8.9	128
3	3.5	7.5	6.1	12.0	3	12.0	12	39	8.0	180
Mean	5.3	9.4	7.1	15.7	4	13.0	14	45	9.0	192
Std dev	1.6	2.3	1.1	3.2	1	2.6	3	8	1.0	71
Treatment, vegetated, 50-75 cm depth										
1	5.0	7.4	6.4	16.0	4	11.0	11	40	5.9	102
2	5.0	8.6	6.8	20.0	6	14.0	12	43	8.9	117
3	5.8	8.5	7.3	17.0	5	13.0	13	42	7.5	134
Mean	5.3	8.2	6.8	17.7	5	12.7	12	42	7.4	118
Std dev	0.5	0.7	0.5	2.1	1	1.5	1	2	1.5	16

TABLE B-4. SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, 0-25 cm depth										
1	5.0	44.0	83.0	6.4	2.1	0.16	<0.05	<0.05	3.0	<0.02
2	5.0	25.0	18.0	5.0	11.0	0.23	<0.05	<0.05	17.0	<0.02
3	6.7	18.0	35.0	5.4	10.0	0.18	<0.05	<0.05	16.0	<0.02
Mean	5.6	29.0	45.3	5.6	7.7	0.19	<0.05	<0.05	12.0	<0.02
Std dev	1.0	13.5	33.7	0.7	4.9	0.04	0.00	0.00	7.8	0.00
Treatment, unvegetated, 0-25 cm depth										
1	11.0	10.0	23.0	4.6	1.5	0.24	<0.05	<0.05	2.3	<0.02
2	15.0	19.0	46.0	5.3	4.0	0.17	<0.05	<0.05	5.4	<0.02
3	18.0	7.4	19.0	5.3	2.3	0.07	<0.05	<0.05	3.5	<0.02
Mean	14.7	12.1	29.3	5.1	2.6	0.16	<0.05	<0.05	3.7	<0.02
Std dev	3.5	6.1	14.6	0.4	1.3	0.09	0.00	0.00	1.6	0.00
Treatment, vegetated, 0-25 cm depth										
1	28.0	14.0	29.0	4.6	6.6	0.20	<0.05	<0.05	9.4	<0.02
2	10.0	14.0	23.0	2.7	3.7	0.21	<0.05	<0.05	5.2	<0.02
3	10.0	12.0	36.0	5.3	3.6	0.18	<0.05	<0.05	5.4	<0.02
Mean	16.0	13.3	29.3	4.2	4.6	0.20	<0.05	<0.05	6.7	<0.02
Std dev	10.4	1.2	6.5	1.3	1.7	0.02	0.00	0.00	2.4	0.00
Control, unvegetated, 25-50 cm depth										
1	2.0	11.0	26.0	6.1	13.0	0.24	<0.05	<0.05	19.0	<0.02
2	3.0	21.0	13.0	5.8	15.0	0.30	<0.05	<0.05	23.0	<0.02
3	5.2	10.0	34.0	8.6	17.0	0.21	<0.05	<0.05	24.0	<0.02
Mean	3.4	14.0	24.3	6.8	15.0	0.25	0.05	0.05	22.0	0.02
Std dev	1.6	6.1	10.6	1.5	2.0	0.05	0.00	0.00	2.6	0.00
Treatment, unvegetated, 25-50 cm depth										
1	14.0	15.0	<1.6	14.0	33.0	0.35	<0.05	<0.05	49.0	<0.02
2	17.0	14.0	<1.2	12.0	27.0	0.44	<0.05	<0.05	38.0	<0.02
3	13.0	9.8	<1.6	8.9	19.0	0.19	<0.05	<0.05	30.0	<0.02
Mean	14.7	12.9	1.5	11.6	26.3	0.33	0.05	0.05	39.0	0.02
Std dev	2.1	2.8	0.2	2.6	7.0	0.13	0.00	0.00	9.5	0.00
Treatment, vegetated, 25-50 cm depth										
1	11.0	10.0	14.0	9.2	17.0	0.22	<0.05	<0.05	25.0	<0.02
2	80.0	21.0	7.2	23.0	51.0	0.32	<0.05	<0.05	78.0	<0.02
3	10.0	12.0	18.0	10.0	21.0	0.30	<0.05	<0.05	30.0	<0.02
Mean	33.7	14.3	13.1	14.1	29.7	0.28	<0.05	<0.05	44.3	<0.02
Std dev	40.1	5.9	5.5	7.7	18.6	0.05	0.00	0.00	29.3	0.00

TABLE B-4. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Na	K	Ca	Mg	Fe	Mn	Co	Mo	Al	Cd
Control, unvegetated, 50-75 cm depth										
1	5.3	14.0	30.0	5.7	8.0	0.11	<0.05	<0.05	12.0	<0.02
2	4.1	13.0	22.0	4.8	11.7	0.21	<0.05	<0.05	18.0	<0.02
3	2.8	17.0	8.6	9.2	22.0	0.23	<0.05	<0.05	32.0	<0.02
Mean	4.1	14.7	20.2	6.6	13.9	0.18	<0.05	<0.05	20.7	<0.02
Std dev	1.3	2.1	10.8	2.3	7.3	0.06	0.00	0.00	10.3	0.00
Treatment, unvegetated, 50-75 cm depth										
1	7.6	8.1	<0.9	11.0	24.0	0.18	<0.05	<0.05	36.0	<0.02
2	17.0	14.0	<8.0	12.0	16.0	0.14	<0.05	<0.05	23.0	<0.02
3	10.0	12.0	<0.7	15.0	32.0	0.29	<0.05	<0.05	48.0	<0.02
Mean	11.5	11.4	3.2	12.7	24.0	0.20	<0.05	<0.05	35.7	<0.02
Std dev	4.9	3.0	4.1	2.1	8.0	0.08	0.00	0.00	12.5	0.00
Treatment, vegetated, 50-75 cm depth										
1	80.0	12.0	4.4	12.0	27.0	0.19	<0.05	<0.05	39.0	<0.02
2	9.0	14.0	12.0	14.0	31.0	0.26	<0.05	<0.05	45.0	<0.02
3	12.0	11.0	11.0	11.0	18.0	0.17	<0.05	<0.05	27.0	<0.02
Mean	33.7	12.3	9.1	12.3	25.3	0.21	<0.05	<0.05	37.0	<0.02
Std dev	40.2	1.5	4.1	1.5	6.7	0.05	0.00	0.00	9.2	0.00

TABLE B-4. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 0-25 cm depth										
1	0.17	<0.05	<0.05	0.31	<0.1	0.14	<0.05	0.25	0.14	<0.50
2	0.24	<0.05	0.06	0.33	<0.1	<0.05	<0.05	0.13	0.60	<0.50
3	0.19	<0.05	0.12	0.19	<0.1	0.06	<0.05	0.12	0.32	<0.50
Mean	0.20	<0.05	<0.08	0.28	<0.1	<0.08	<0.05	0.17	0.35	<0.50
Std dev	0.04	0.00	0.04	0.08	0.0	0.05	0.00	0.07	0.23	0.00
Treatment, unvegetated, 0-25 cm depth										
1	0.12	<0.05	<0.05	<0.06	<0.1	0.16	<0.05	0.07	0.26	<0.50
2	0.32	<0.05	0.05	0.72	<0.1	0.21	<0.05	0.10	0.06	<0.50
3	0.19	<0.05	<0.05	<0.06	<0.1	0.15	<0.05	<0.05	0.07	<0.50
Mean	0.21	<0.05	<0.05	<0.28	<0.1	0.17	<0.05	<0.07	0.13	<0.50
Std dev	0.10	0.00	0.00	0.38	0.0	0.03	0.00	0.03	0.11	0.00
Treatment, vegetated, 0-25 cm depth										
1	0.47	0.08	0.17	0.91	0.1	0.13	<0.05	0.12	0.08	<0.50
2	0.33	0.05	<0.05	0.57	<0.1	0.08	<0.05	0.07	<0.05	<0.50
3	0.39	<0.05	0.05	0.51	<0.1	0.17	<0.05	0.08	0.07	<0.50
Mean	0.40	<0.06	<0.09	0.66	<0.1	0.13	<0.05	0.09	<0.07	<0.50
Std dev	0.07	0.02	0.07	0.22	0.0	0.05	0.00	0.03	0.02	0.00
Control, unvegetated, 25-50 cm depth										
1	0.72	<0.05	0.17	1.50	<0.1	<0.05	<0.05	0.26	0.18	<0.50
2	0.19	<0.05	<0.05	0.21	<0.1	<0.05	<0.05	0.14	0.16	0.57
3	0.15	<0.05	0.05	0.38	<0.1	0.08	<0.05	0.23	0.19	0.69
Mean	0.35	<0.05	<0.09	0.70	<0.1	<0.06	<0.05	0.21	0.18	<0.59
Std dev	0.32	0.00	0.07	0.70	0.0	0.02	0.00	0.06	0.02	0.10
Treatment, unvegetated, 25-50 cm depth										
1	0.15	<0.05	<0.05	<0.05	<0.1	0.06	0.06	0.21	0.43	1.20
2	0.18	<0.05	0.06	<0.05	<0.1	<0.05	0.06	0.12	0.16	1.00
3	0.08	<0.05	<0.05	<0.05	<0.1	0.06	0.06	0.14	0.23	0.80
Mean	0.14	<0.05	<0.05	<0.05	<0.1	<0.06	0.06	0.16	0.27	1.00
Std dev	0.05	0.00	0.01	0.00	0.0	0.01	0.00	0.05	0.14	0.20
Treatment, vegetated, 2550 cm depth										
1	0.25	<0.05	<0.05	0.22	<0.1	0.06	<0.05	0.12	0.08	0.68
2	0.28	0.08	0.08	0.23	0.1	0.05	0.12	0.27	0.15	1.30
3	0.30	<0.05	0.05	0.37	<0.1	0.08	<0.05	0.18	0.07	0.75
Mean	0.28	<0.06	<0.06	0.27	<0.1	0.06	<0.07	0.19	0.10	0.91
Std dev	0.03	0.02	0.02	0.08	0.0	0.02	0.04	0.08	0.04	0.34

TABLE B-4. (CONTINUED) SOLUBLE SOIL METALS (MG/KG), NON-COMPOSITED SAMPLES, FIELD STUDY, 6/84.

Replication	Cu	Cr	Ni	Zn	Pb	Sr	V	Ba	B	Ti
Control, unvegetated, 50-75 cm depth										
1	0.06	<0.05	<0.05	<0.05	<0.1	0.07	<0.05	0.12	0.25	<0.50
2	0.16	<0.05	<0.05	0.17	<0.1	0.05	<0.05	0.15	0.30	<0.50
3	0.25	<0.05	0.07	0.30	<0.1	<0.05	<0.05	0.16	0.22	0.74
Mean	0.16	<0.05	<0.06	<0.17	<0.1	<0.06	<0.05	0.14	0.26	<0.58
Std dev	0.10	0.00	0.01	0.13	0.0	0.01	0.00	0.02	0.04	0.14
Treatment, unvegetated, 50-75 cm depth										
1	0.06	<0.05	<0.05	<0.05	<0.1	<0.05	0.06	0.11	0.27	0.89
2	0.06	<0.05	<0.05	<0.05	<0.1	0.06	<0.05	0.11	0.36	0.57
3	0.08	0.05	0.20	<0.05	<0.1	<0.05	0.07	0.16	0.29	1.20
Mean	0.07	<0.05	<0.10	<0.05	0.1	<0.05	<0.06	0.13	0.31	0.89
Std dev	0.01	0.00	0.09	0.00	0.0	0.01	0.01	0.03	0.05	0.32
Treatment, vegetated, 50-75 cm depth										
1	0.21	<0.05	0.06	0.15	<0.1	<0.05	0.08	0.12	0.09	0.85
2	0.18	<0.05	<0.05	0.41	<0.1	0.07	0.06	0.18	0.08	1.10
3	0.13	<0.05	<0.05	0.09	<0.1	0.05	<0.05	0.11	0.06	0.75
Mean	0.17	<0.05	<0.05	0.22	<0.1	<0.06	<0.06	0.14	0.08	0.90
Std dev	0.04	0.00	0.01	0.17	0.0	0.01	0.02	0.04	0.02	0.18

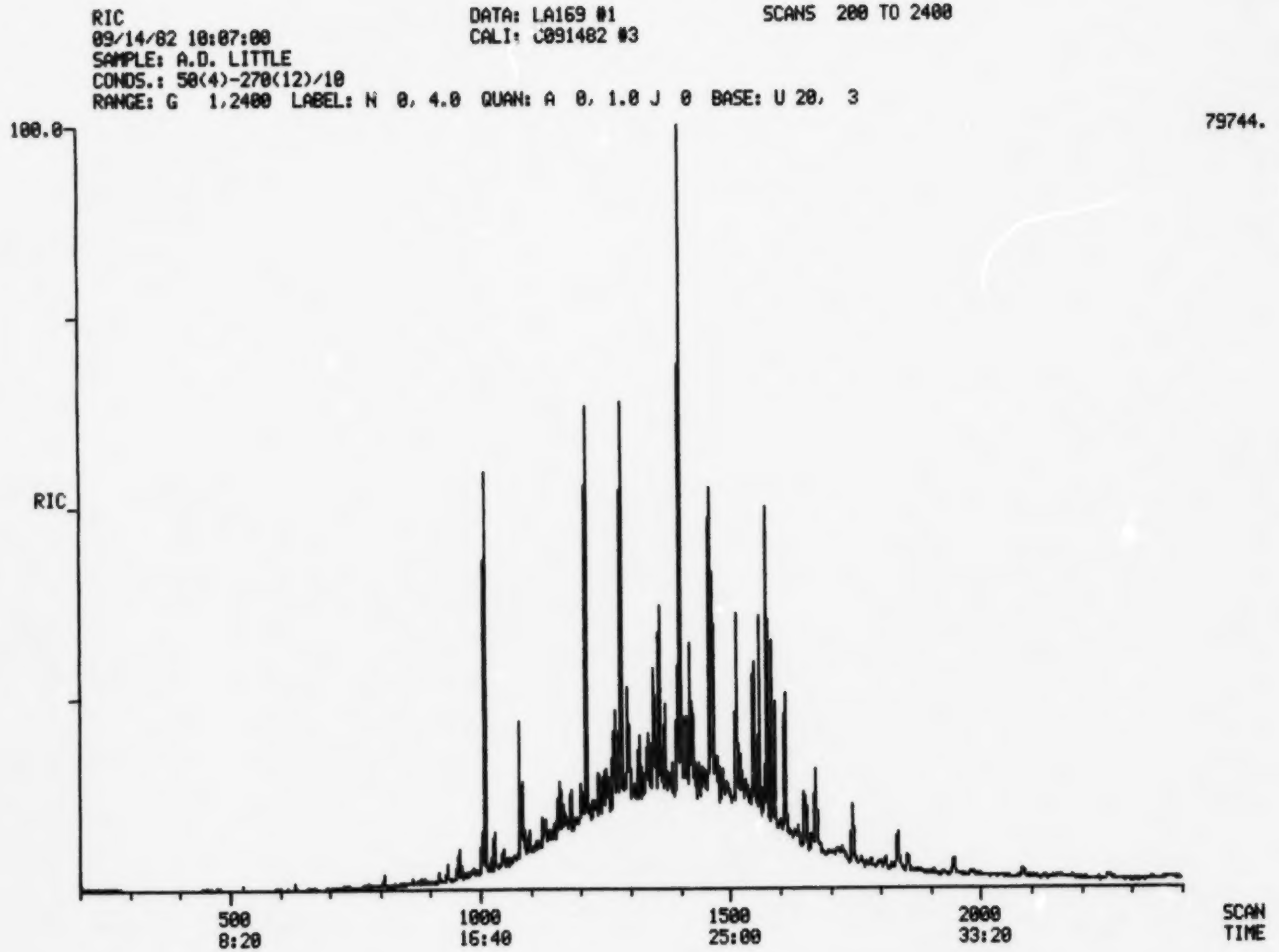

Figure C-1 Reconstruction chromatogram of greenhouse soil, site OP, August 1982, treated pots, surface sample.

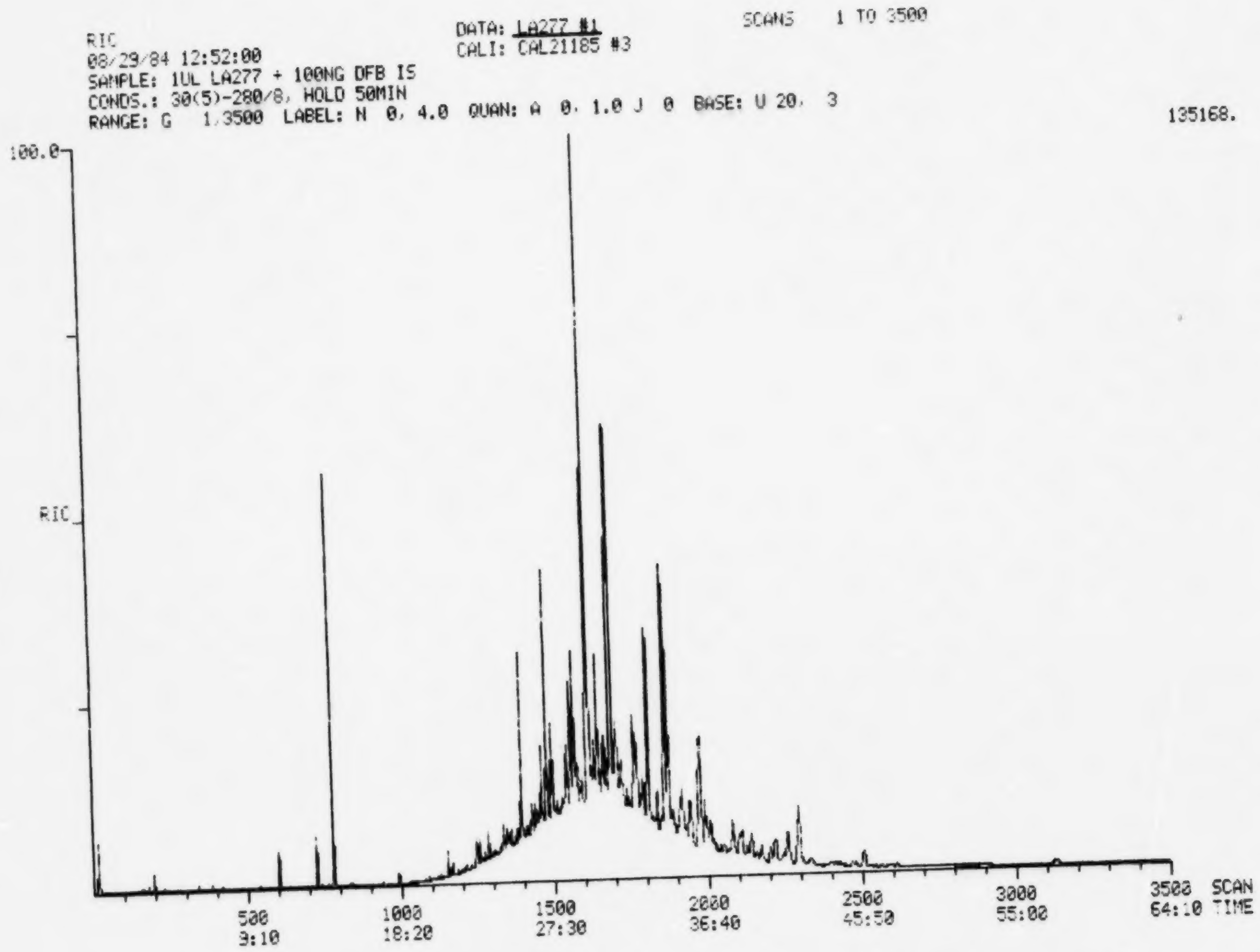

Figure C-2 Reconstruction chromatogram of greenhouse soil, site OP, June 1984, treated pots, surface sample.

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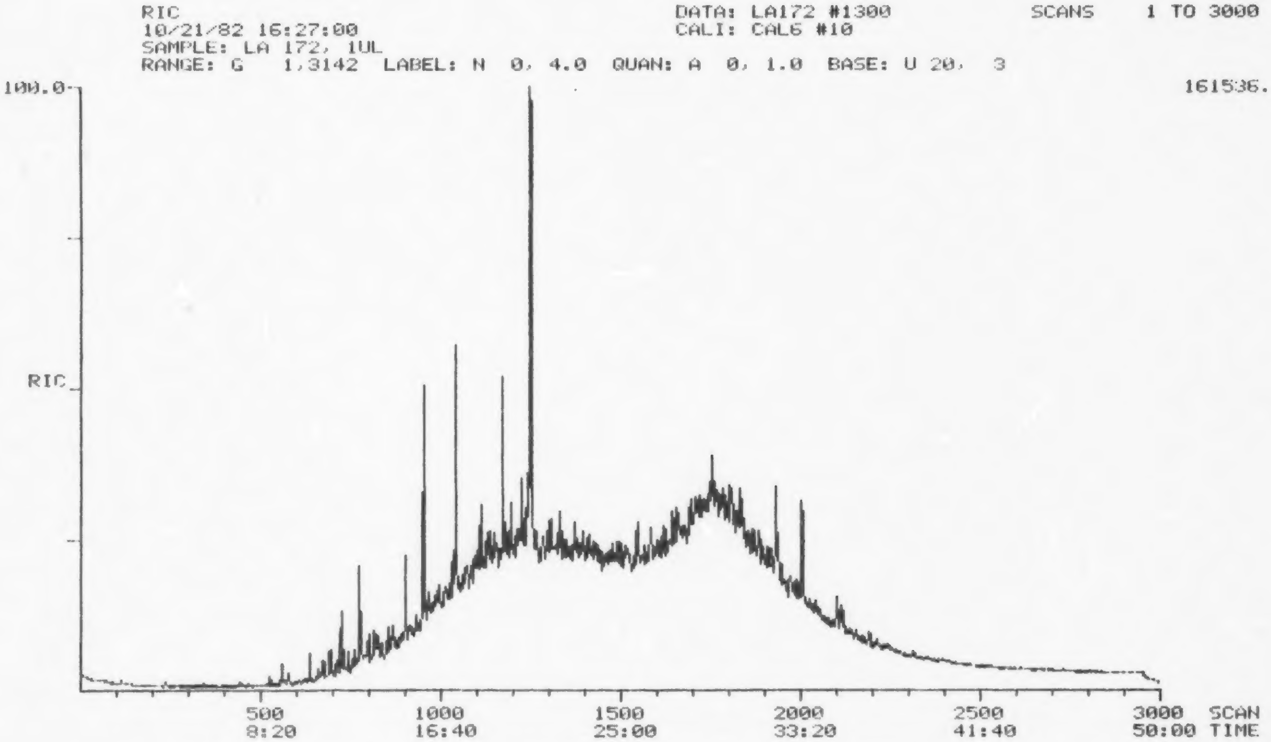

C-3 Reconstruction chromatogram of greenhouse soil, site TX, August 1982, treated pots, surface sample.

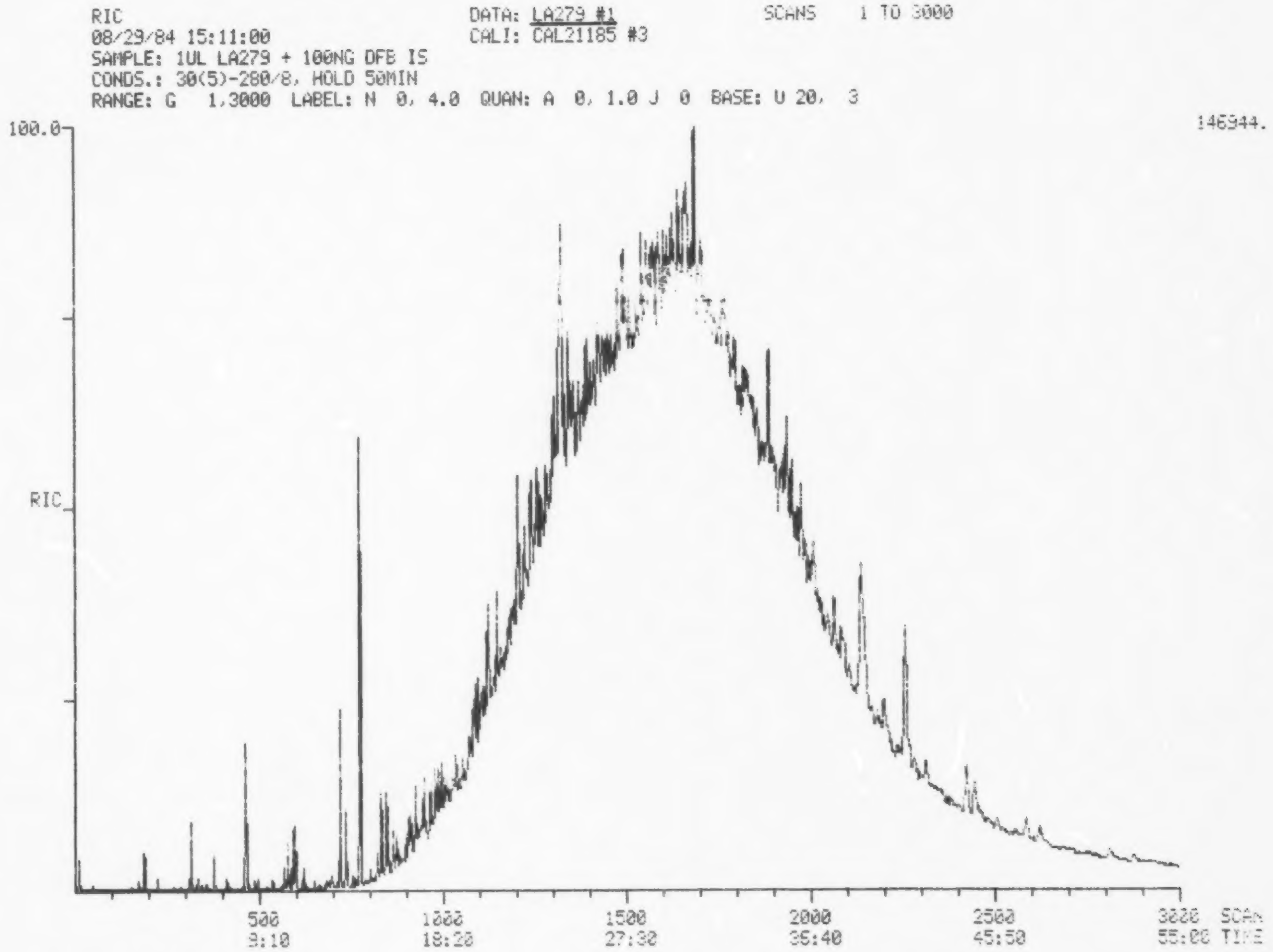

Figure C-4 Reconstruction chromatogram of greenhouse soil, site TX, June 1984, treated pots. surface sample.

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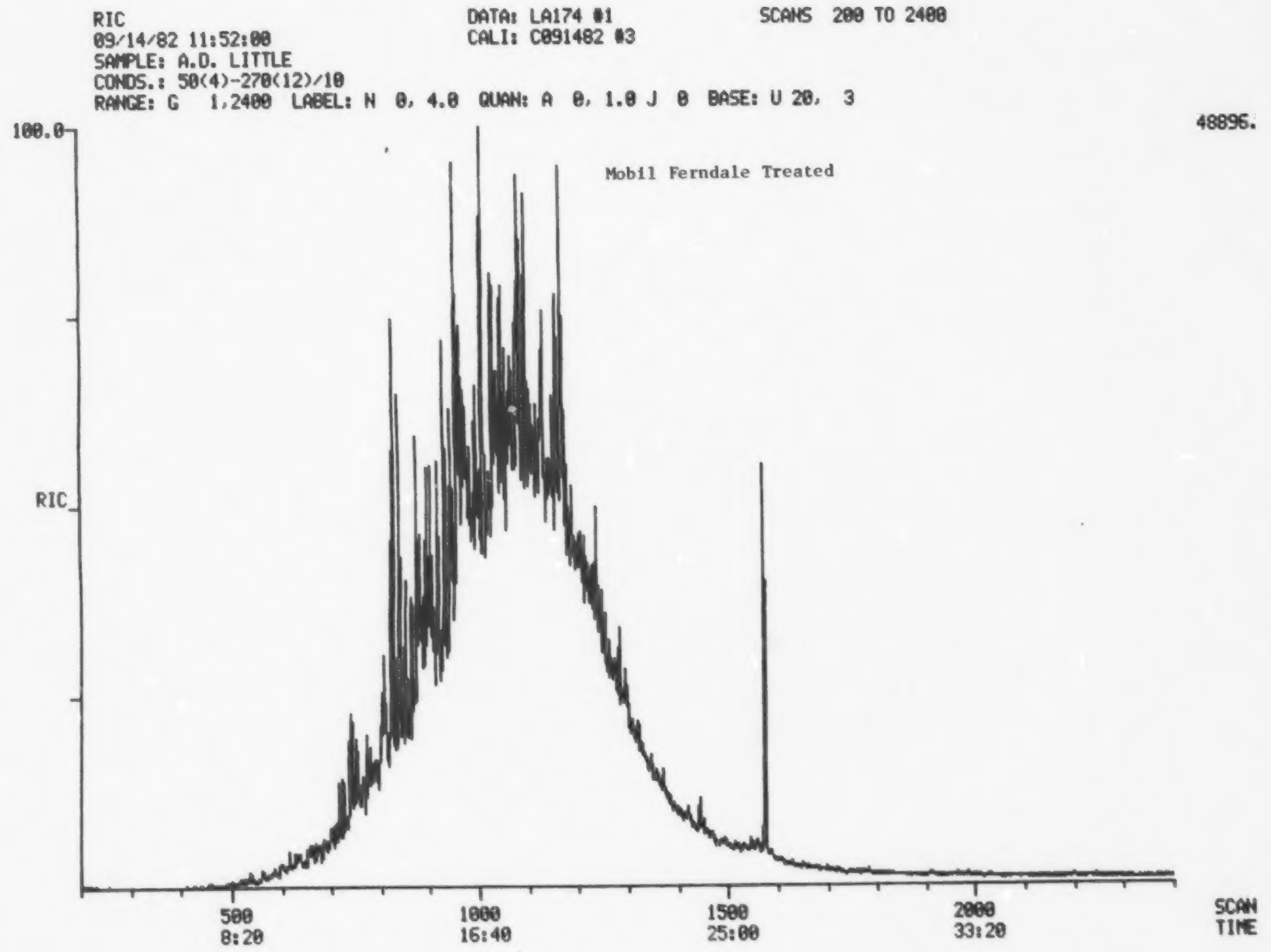
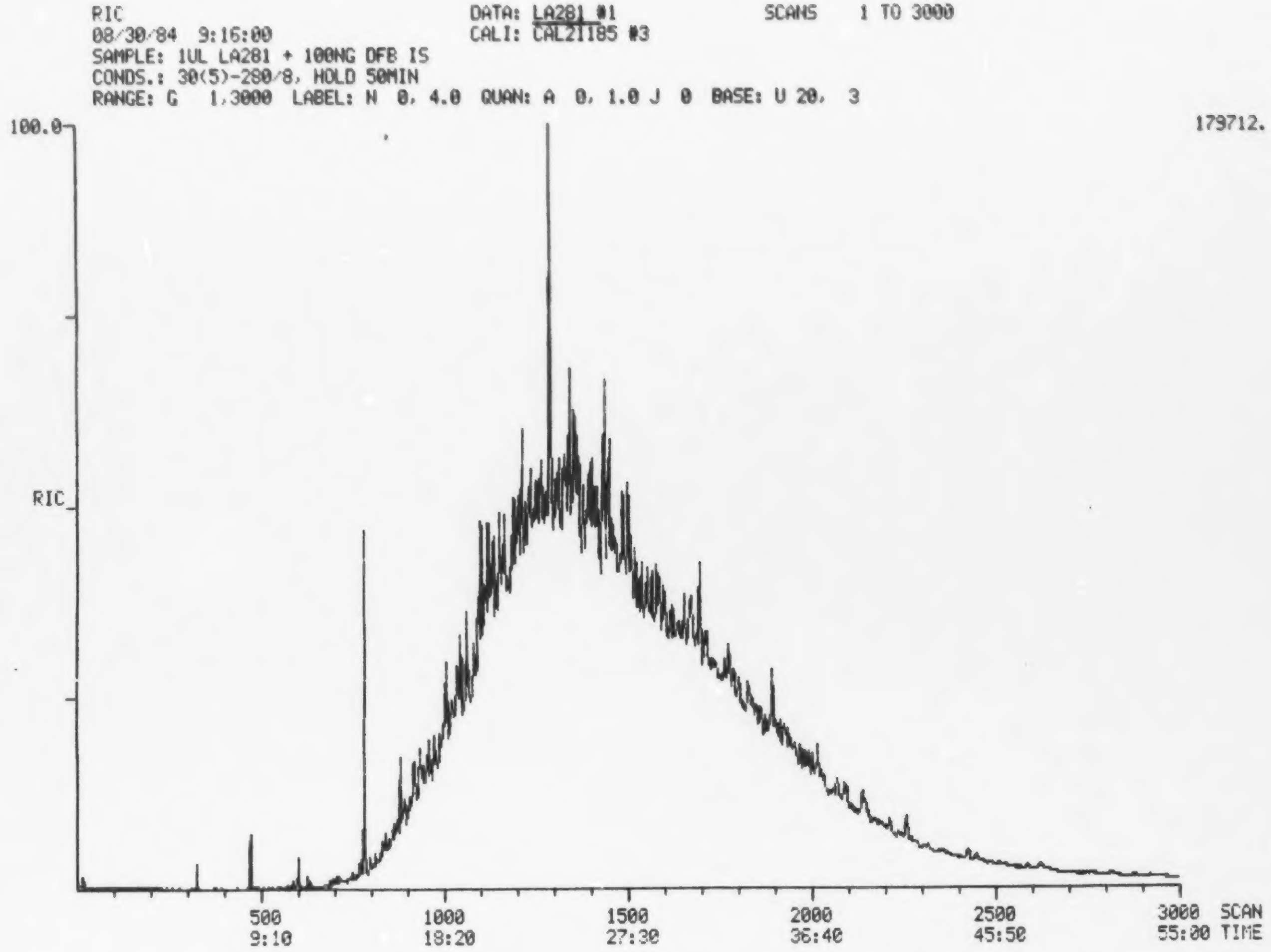


Figure C-5 Reconstruction chromatogram of greenhouse soil, site WA, August 1982, treated pots, surface sample.



```
RIC                                    DATA: LA281 #1          SCANS    1 TO 3000
08/30/84  9:16:00                      CALI: CAL21185 #3
SAMPLE: 1UL LA281 + 100NG DFB IS
CONDS.: 30(5)-280/8, HOLD 50MIN
RANGE: G   1,3000  LABEL: N  0, 4.0  QUAN: A  0, 1.0 J  0  BASE: U 20,  3
```

Figure C-6 Reconstruction chromatogram of greenhouse soil, site WA, June 1984, treated pots, surface sample.

Control

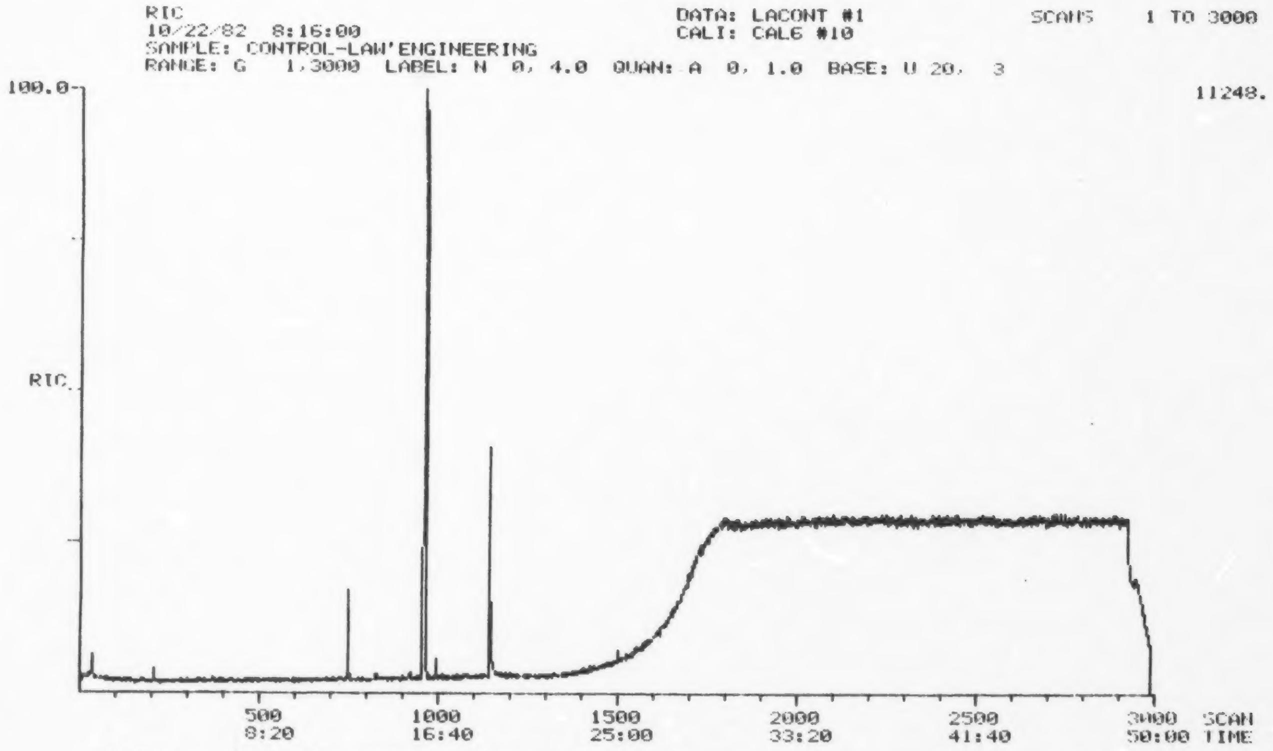
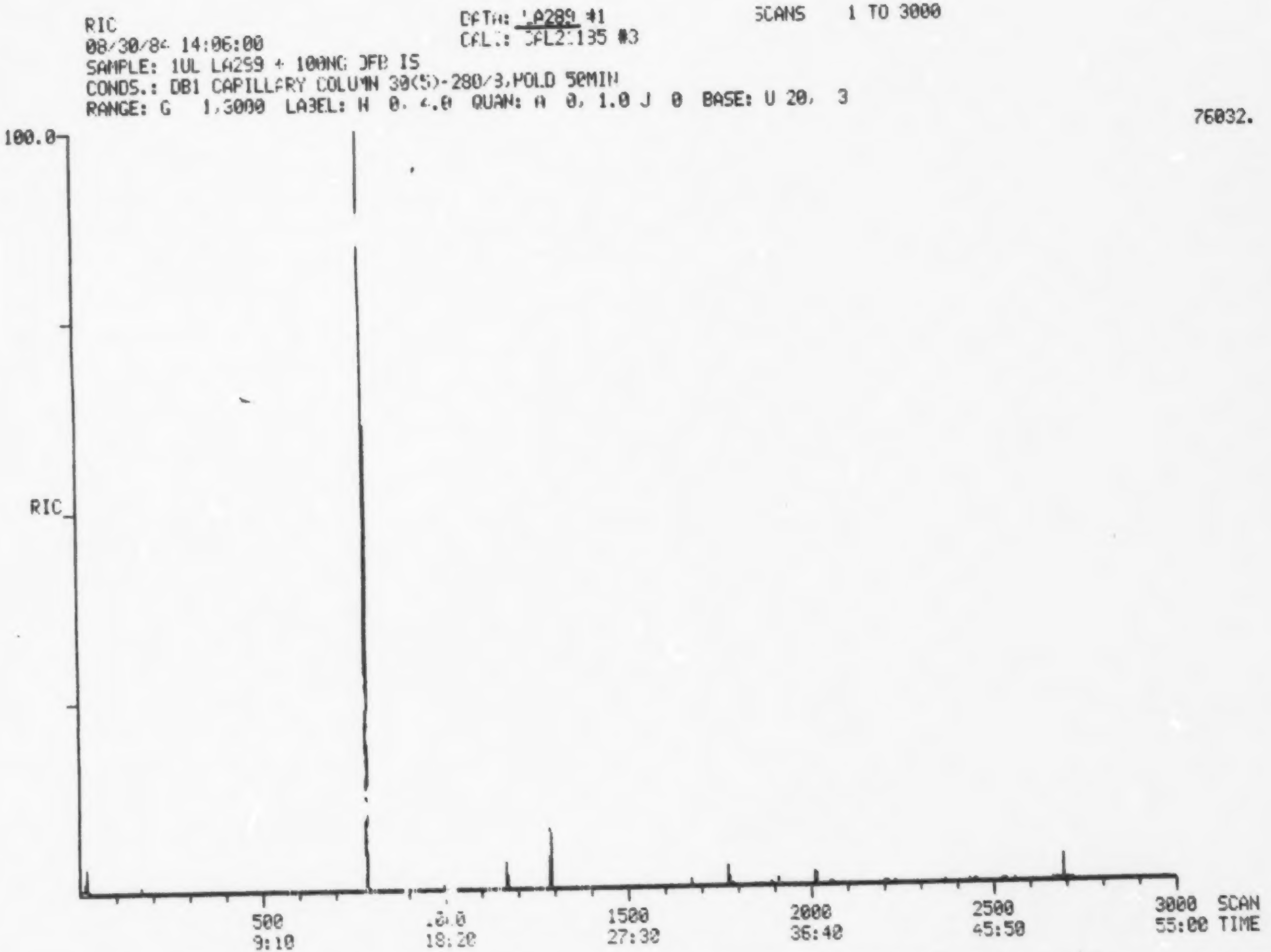


Figure C-7 Reconstruction chromatogram of composite greenhouse soil, site OT, TX, WA, August 1982, control pots. surface sample.



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RIC                                  DATA: LA289 #1            SCANS    1 TO 3000
08/30/84 14:06:00                    CAL.: CAL2:135 #3
SAMPLE: 1UL LA299 + 100NG DFB IS
CONDS.: DB1 CAPILLARY COLUMN 30(5)-280/3,HOLD 50MIN
RANGE: G   1,3000  LABEL: H  0, 4.0  QUAN: A  0, 1.0 J  0  BASE: U 20,  3
                                                                              76032.
```

Figure C-8 Reconstruction chromatogram of greenhouse soil, site WA, June 1984, control pots. surface sample.

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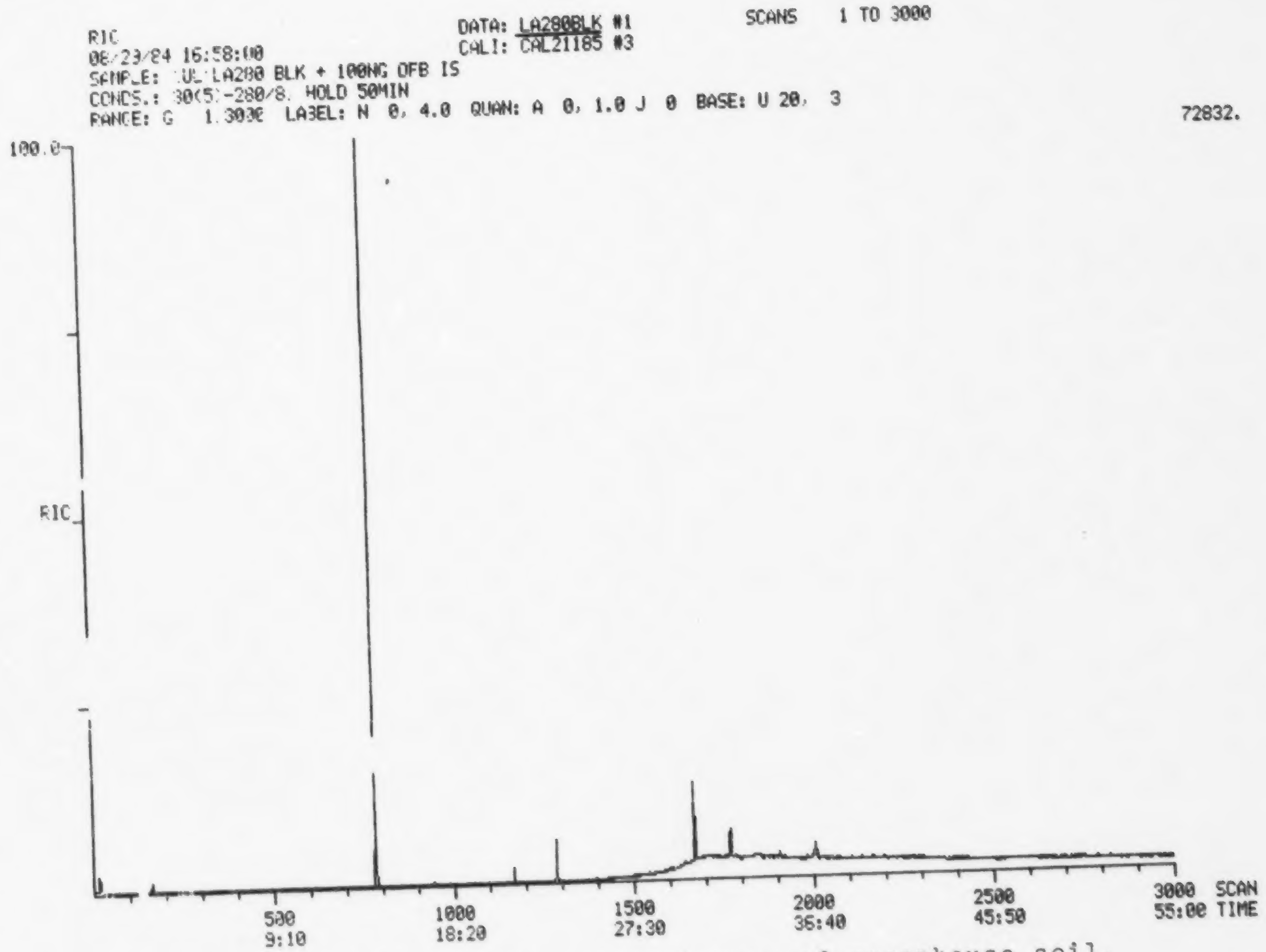

Figure C-9 Reconstruction chromatogram of greenhouse soil, site TX. control pots. subsurface sample.

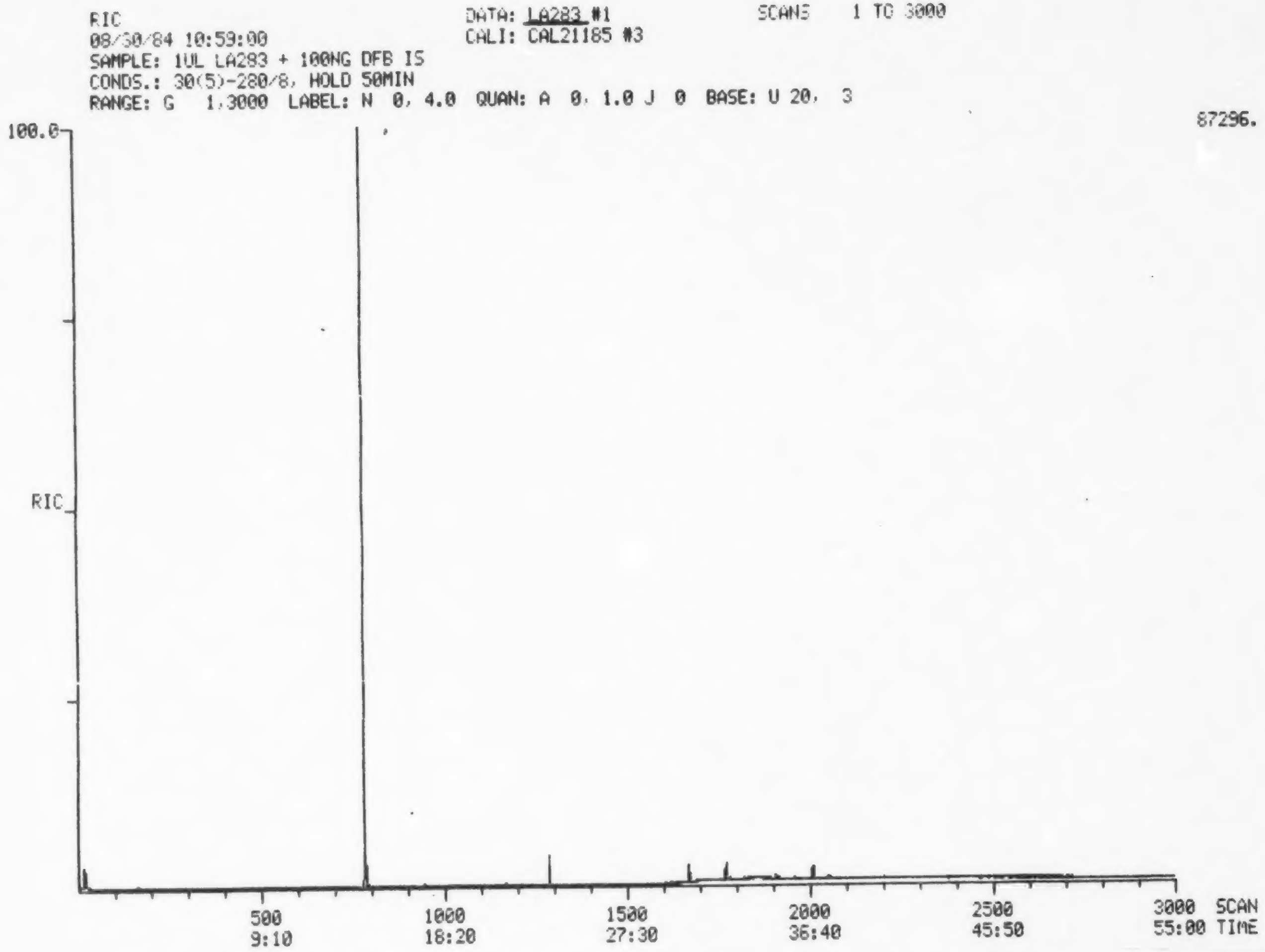

Figure C-10 Reconstruction chromatogram of field soil, June 1984, control plots, surface sample.

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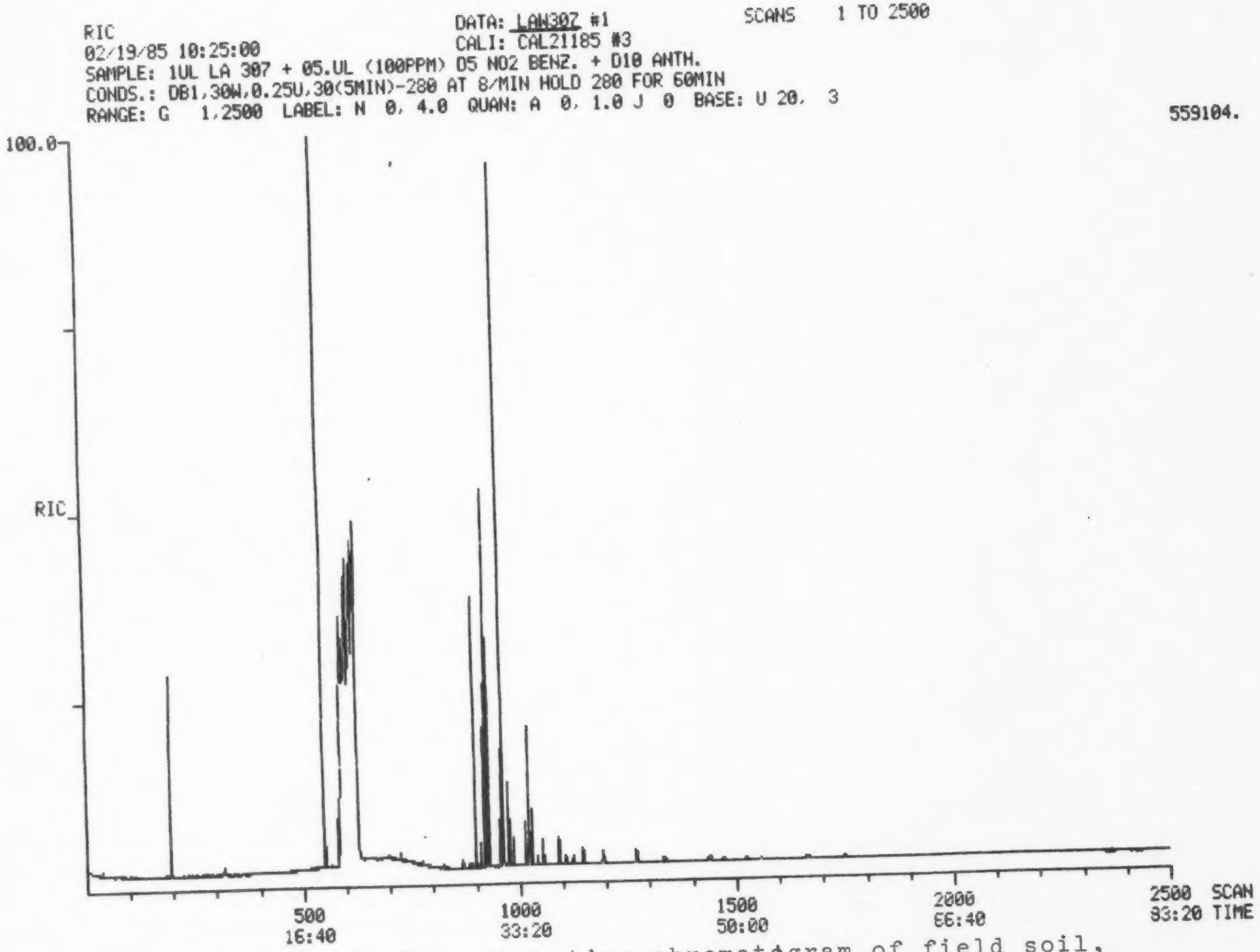
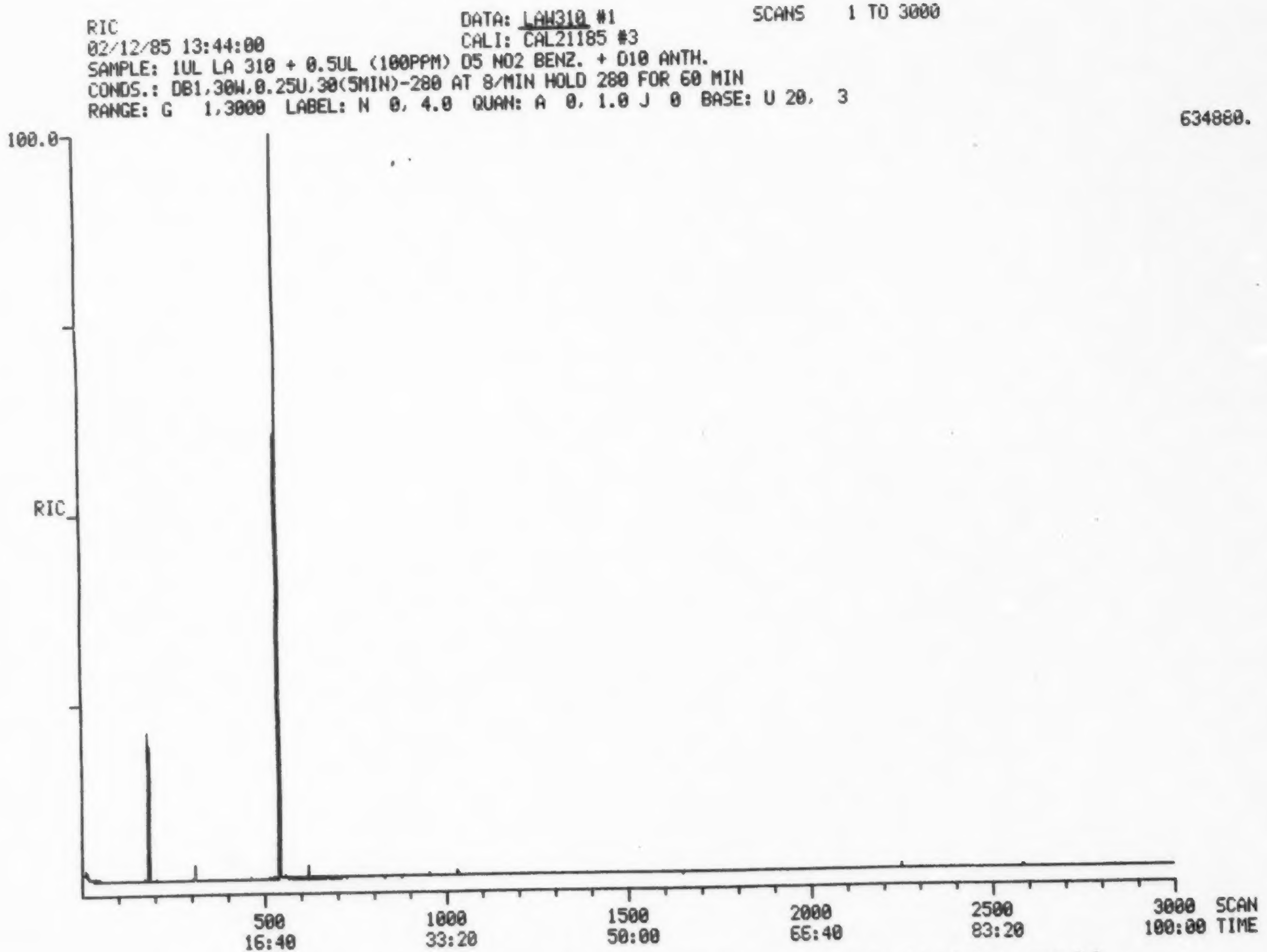


RIC
02/19/85 10:25:00
DATA: LAW307 #1 SCANS 1 TO 2500
CALI: CAL21185 #3
SAMPLE: 1UL LA 307 + 05.UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN HOLD 280 FOR 60MIN
RANGE: G 1,2500 LABEL: N 0, 4.0 QUAN: A 0, 1.0 J 0 BASE: U 20, 3
559104.

Figure C-11 Reconstruction chromatogram of field soil, November 1984, unvegetated plots, surface sample.



```
RIC                                 DATA: LAW310 #1           SCANS    1 TO 3000
02/12/85 13:44:00                   CALI: CAL21185 #3
SAMPLE: 1UL LA 310 + 0.5UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN HOLD 280 FOR 60 MIN
RANGE: G   1,3000  LABEL: N  0, 4.0  QUAN: A  0, 1.0 J  0  BASE: U 20,  3
```

Figure C-12 Reconstruction chromatogram of field runoff,
November 1984, unvegetated plots, filtered sample.

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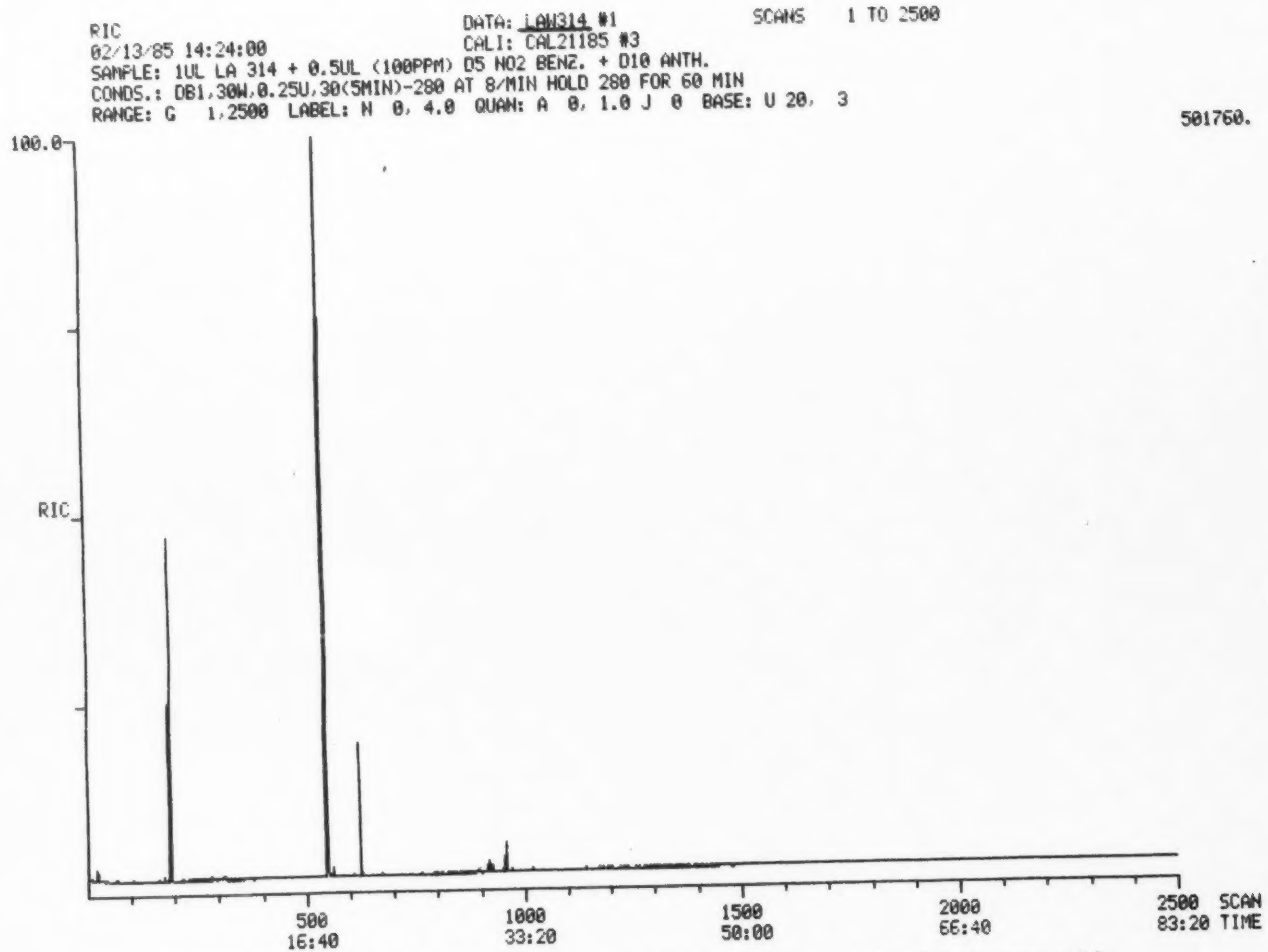
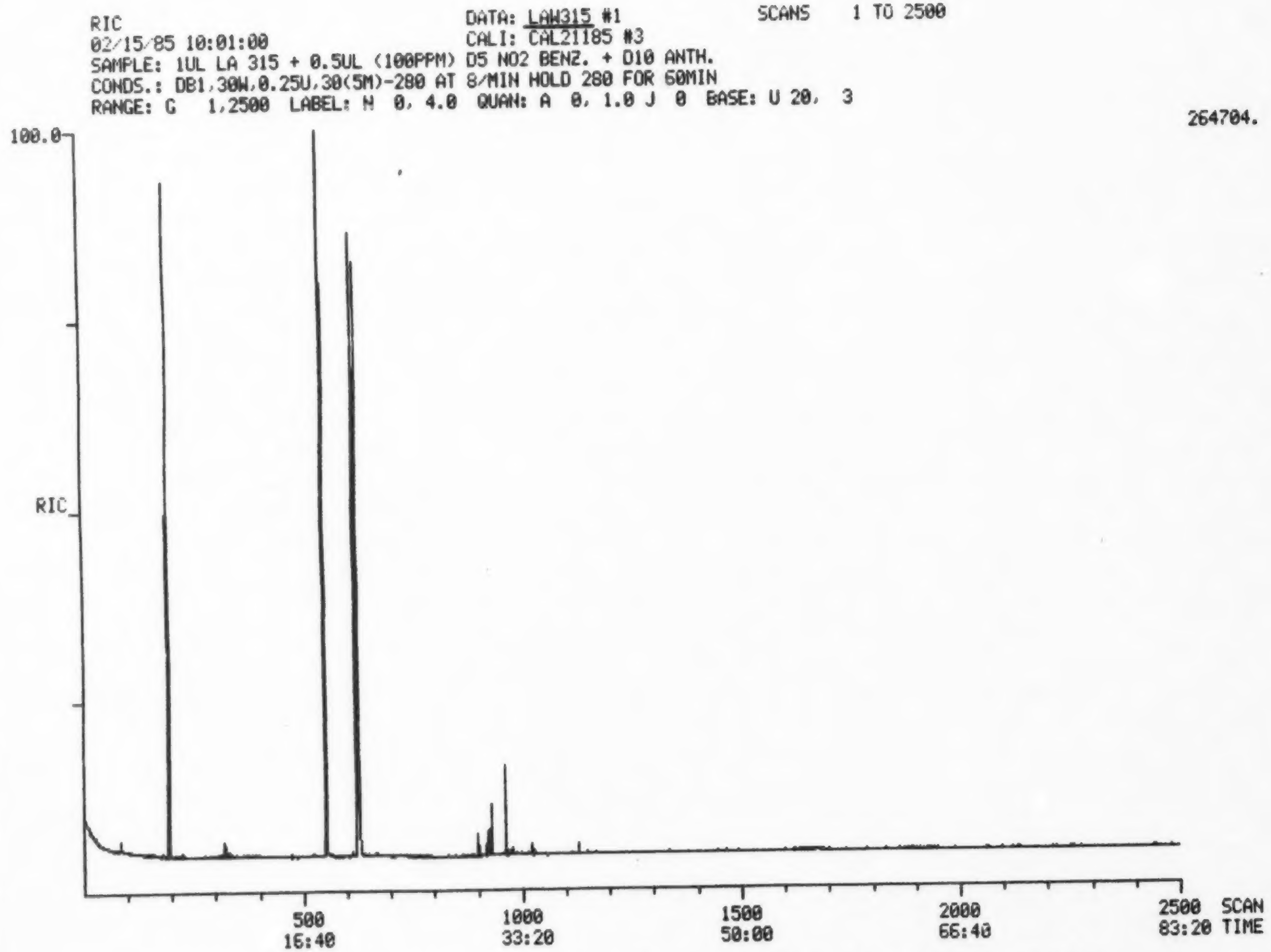


Figure C-13 Reconstruction chromatogram of field runoff, November 1984, control plots, filtered sample.



```
RIC                                        DATA: LAW315 #1          SCANS    1 TO 2500
02/15/85 10:01:00                          CALI: CAL21185 #3
SAMPLE: 1UL LA 315 + 0.5UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5M)-280 AT 8/MIN HOLD 280 FOR 60MIN
RANGE: G   1,2500  LABEL: N  0, 4.0  QUAN: A  0, 1.0 J  0  BASE: U 20,  3
                                                                                  264704.
```

Figure C-14 Reconstruction chromatogram of field runoff, November 1984, control plots, unfiltered sample.

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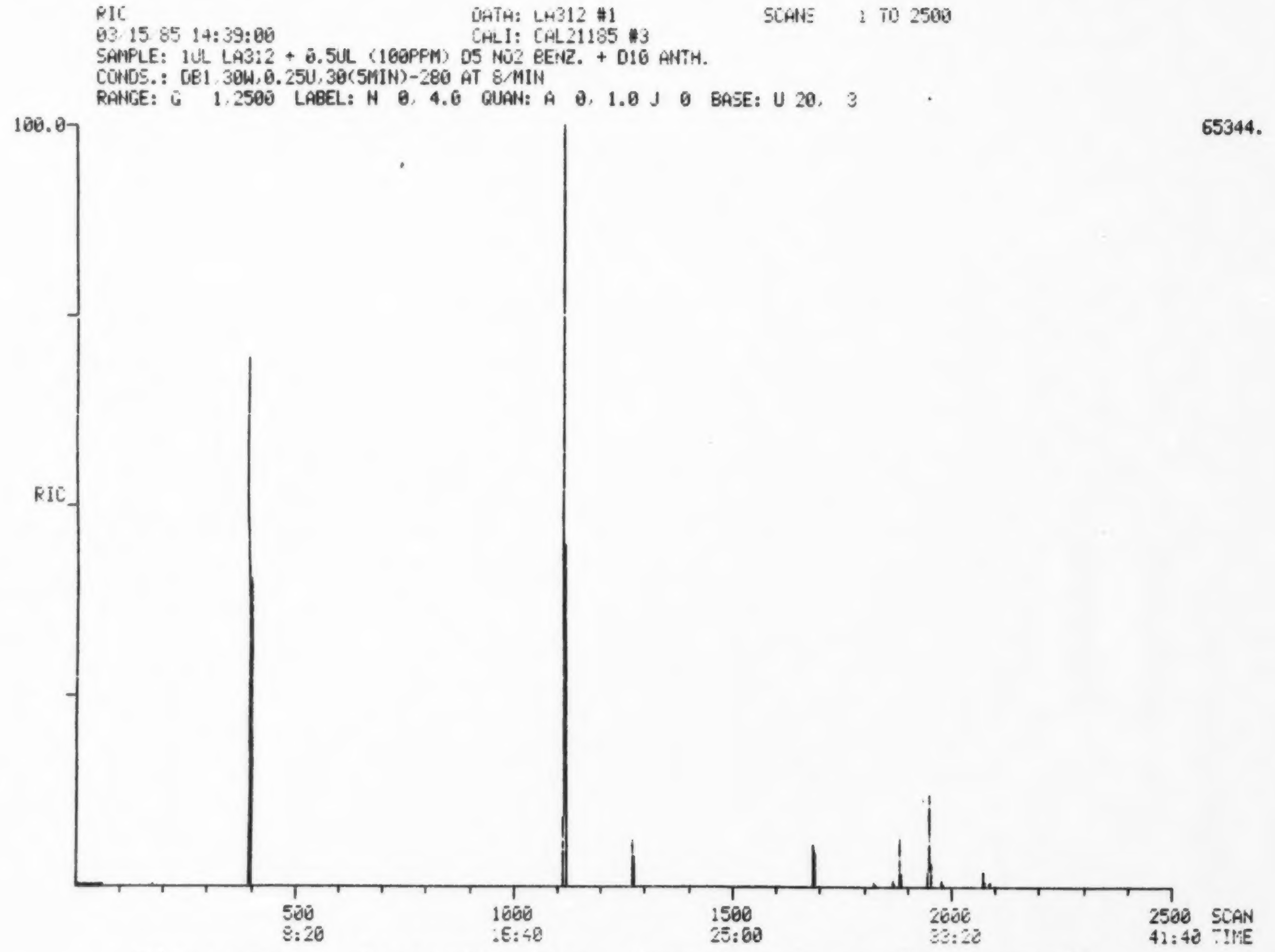

Figure C-15 Reconstruction chromatogram of field runoff, November 1984, vegetated plots, filtered sample.

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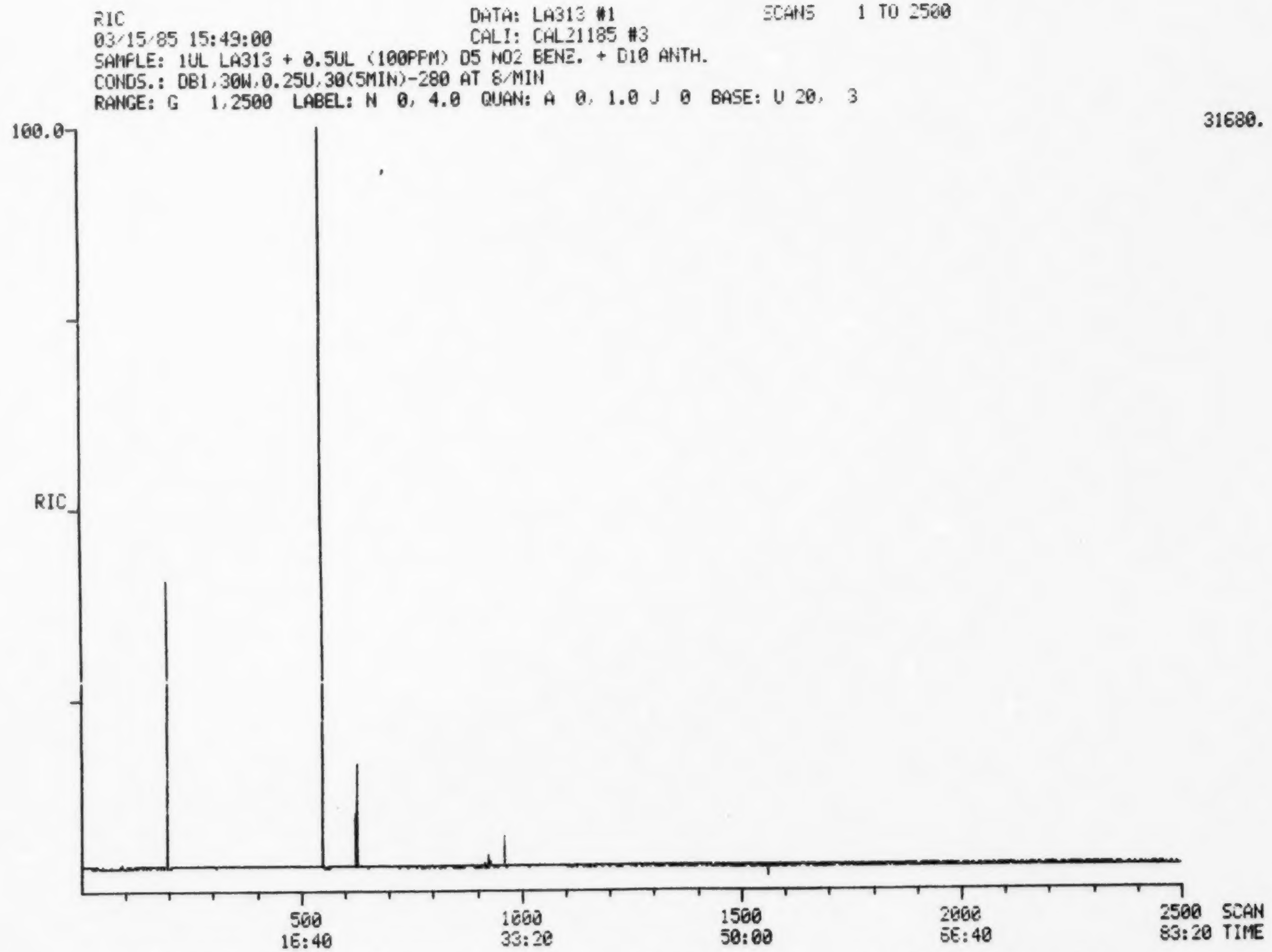


```
RIC                                     DATA: LA313 #1          SCANS   1 TO 2500
03/15/85 15:49:00                       CALI: CAL21185 #3
SAMPLE: 1UL LA313 + 0.5UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN
RANGE: G   1,2500  LABEL: N  0, 4.0  QUAN: A  0, 1.0 J  0  BASE: U 20,  3
```

Figure C-16 Reconstruciton chromatogram of field runoff,
November 1984, vegetated plots, unfiltered sample.

Reproduced from
best available copy.

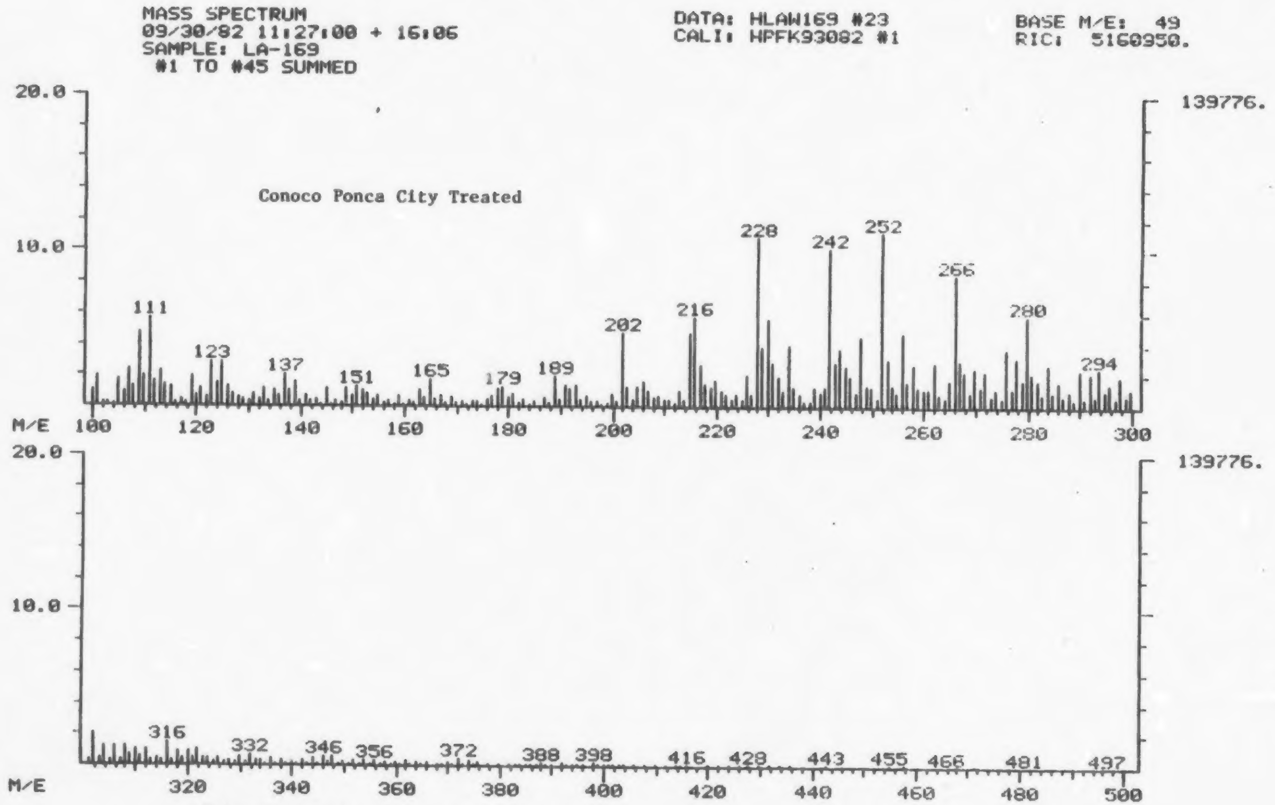


Figure C -17 Mass spectrum of greenhouse soil, site OP, August 1982, treated pots, surface sample.

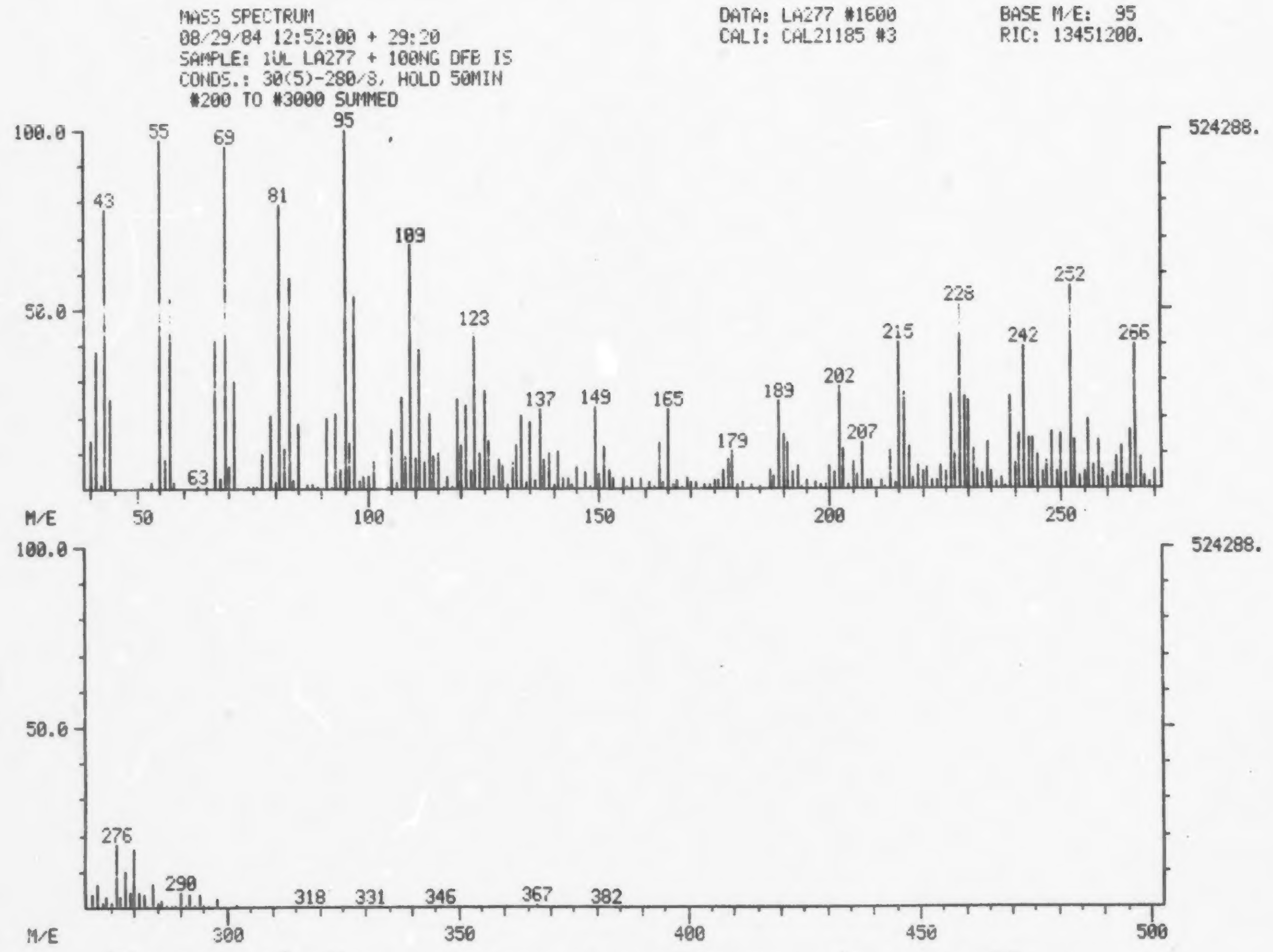


Figure C-18 Mass spectrum of greenhouse soil, site OP, June 1984, treated pots, surface sample.

Exxon Baytown Treated

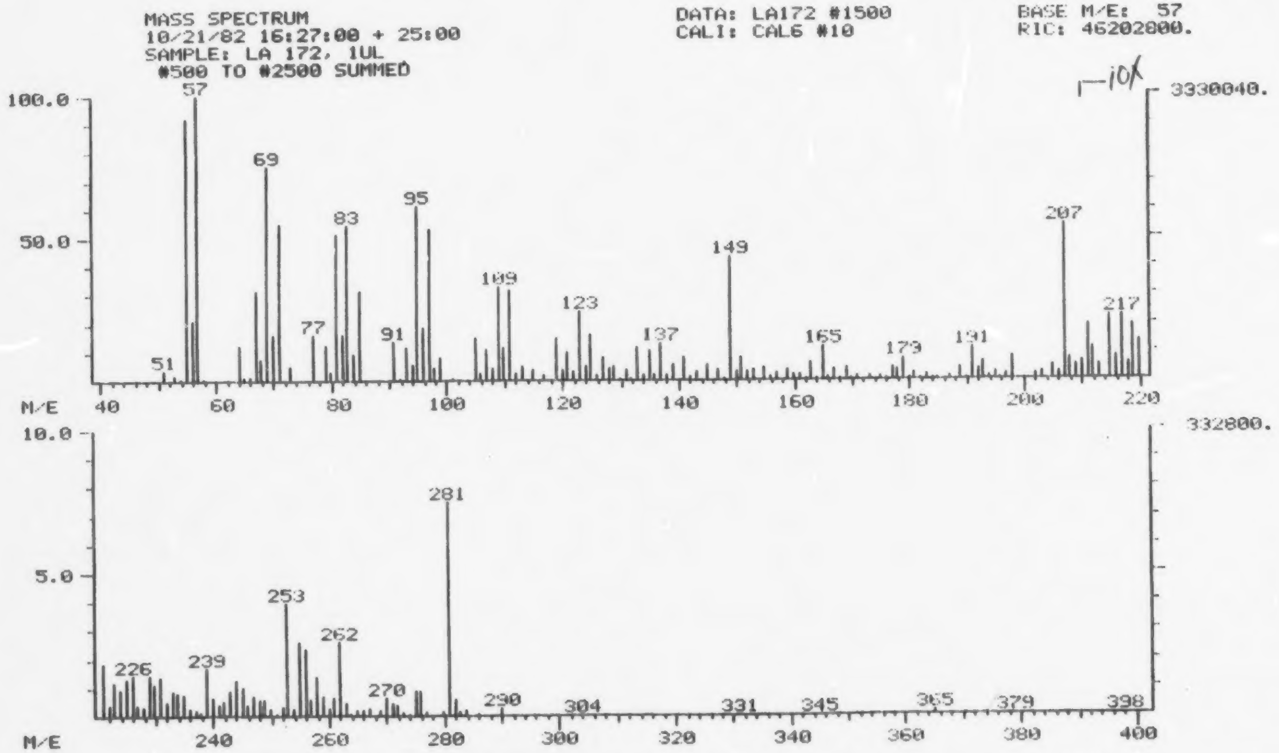


Figure C-19 Mass spectrum of greenhouse soil, site TX, August 1982, treated pots, surface sample.

Reproduced from best available copy.

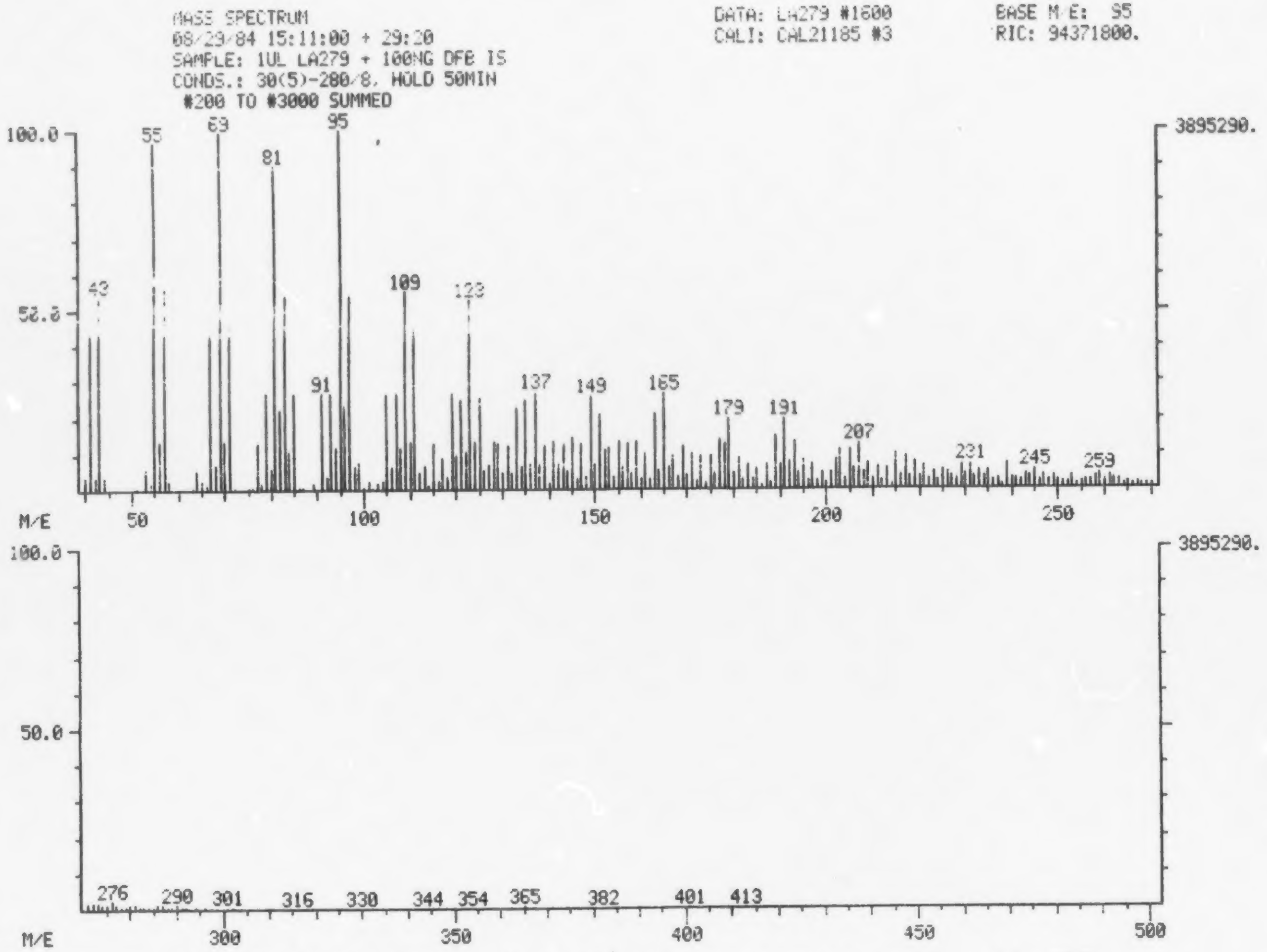


Figure C-20 Mass spectrum of greenhouse soil, site TX, June 1984, treated pots, surface sample,

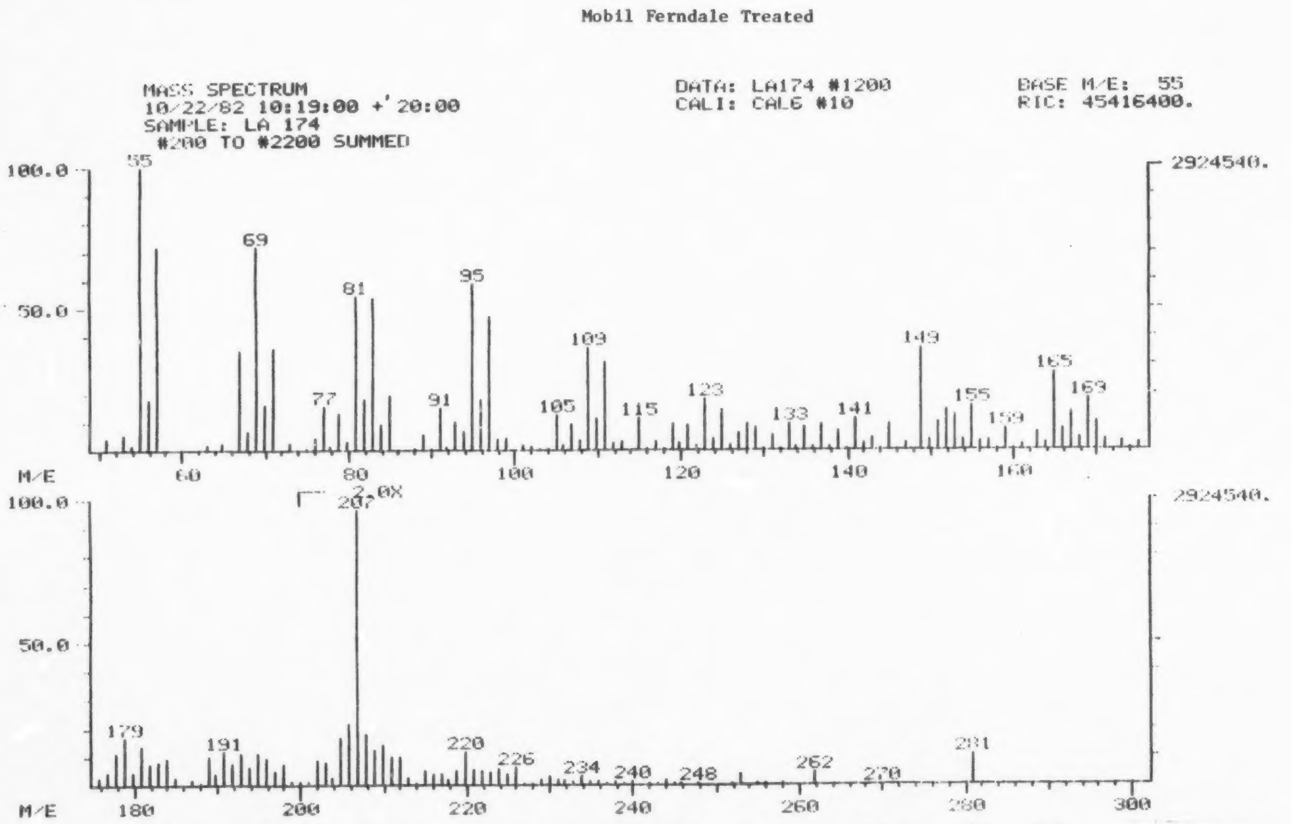


Figure C-21 Mass spectrum of greenhouse soil, site WA, August 1982, treated pots. surface sample.

Reproduced from best available copy.

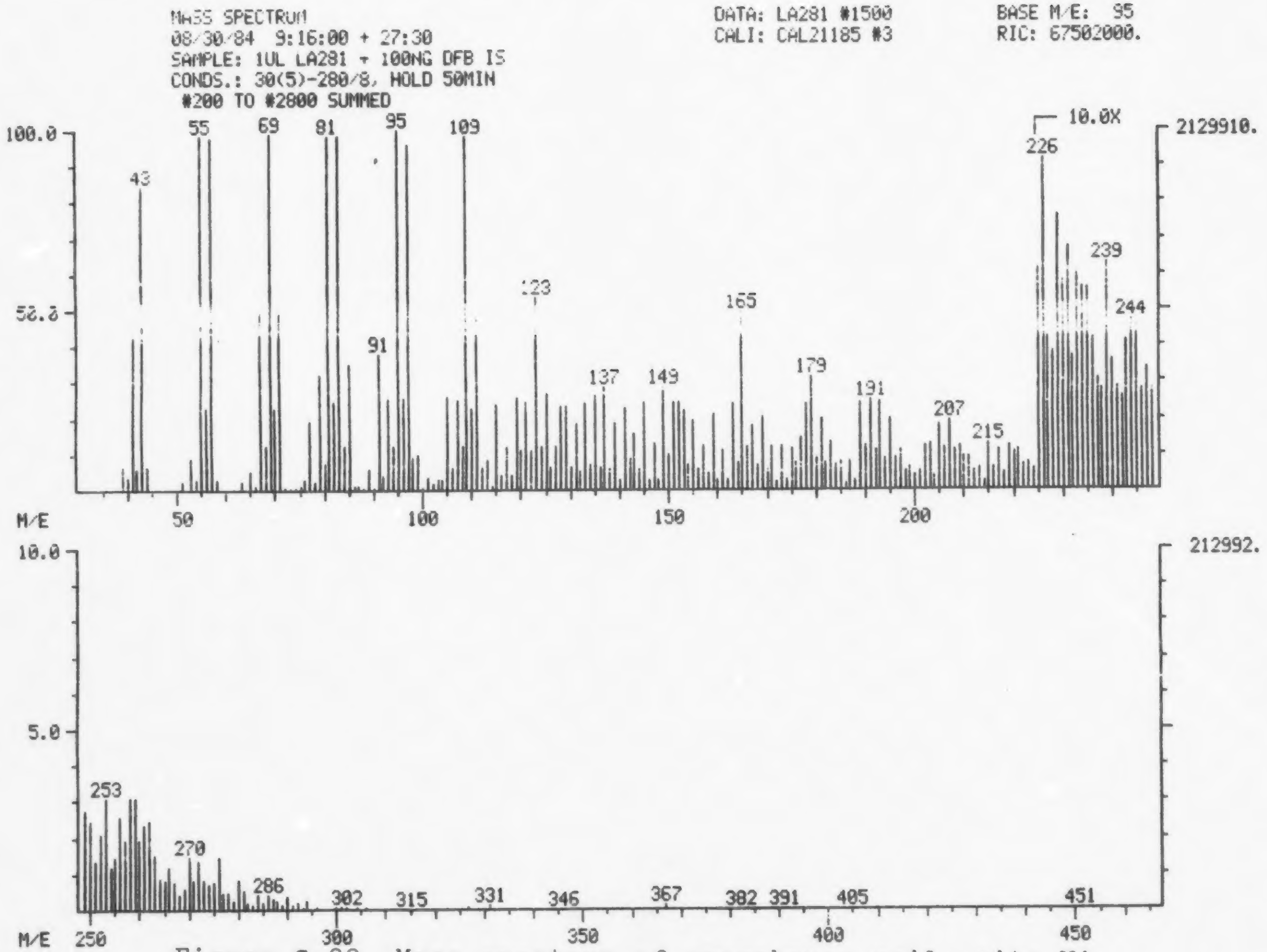


Figure C-22 Mass spectrum of greenhouse soil, site WA, June 1984, treated pots, surface sample.

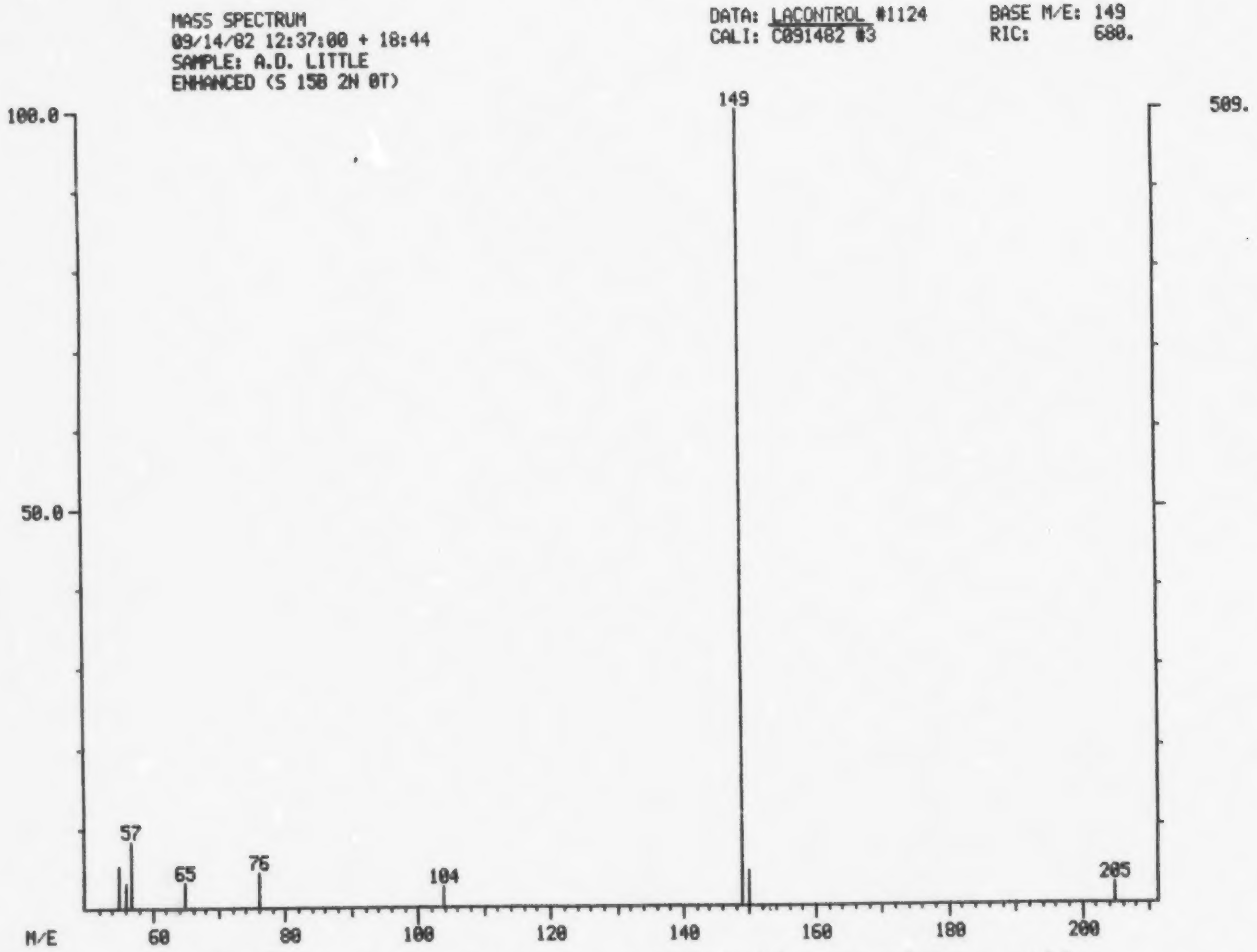


Figure C-23 Mass spectrum of composite greenhouse soil, sites OT, TX, WA, August 1982, control pots, surface sample.

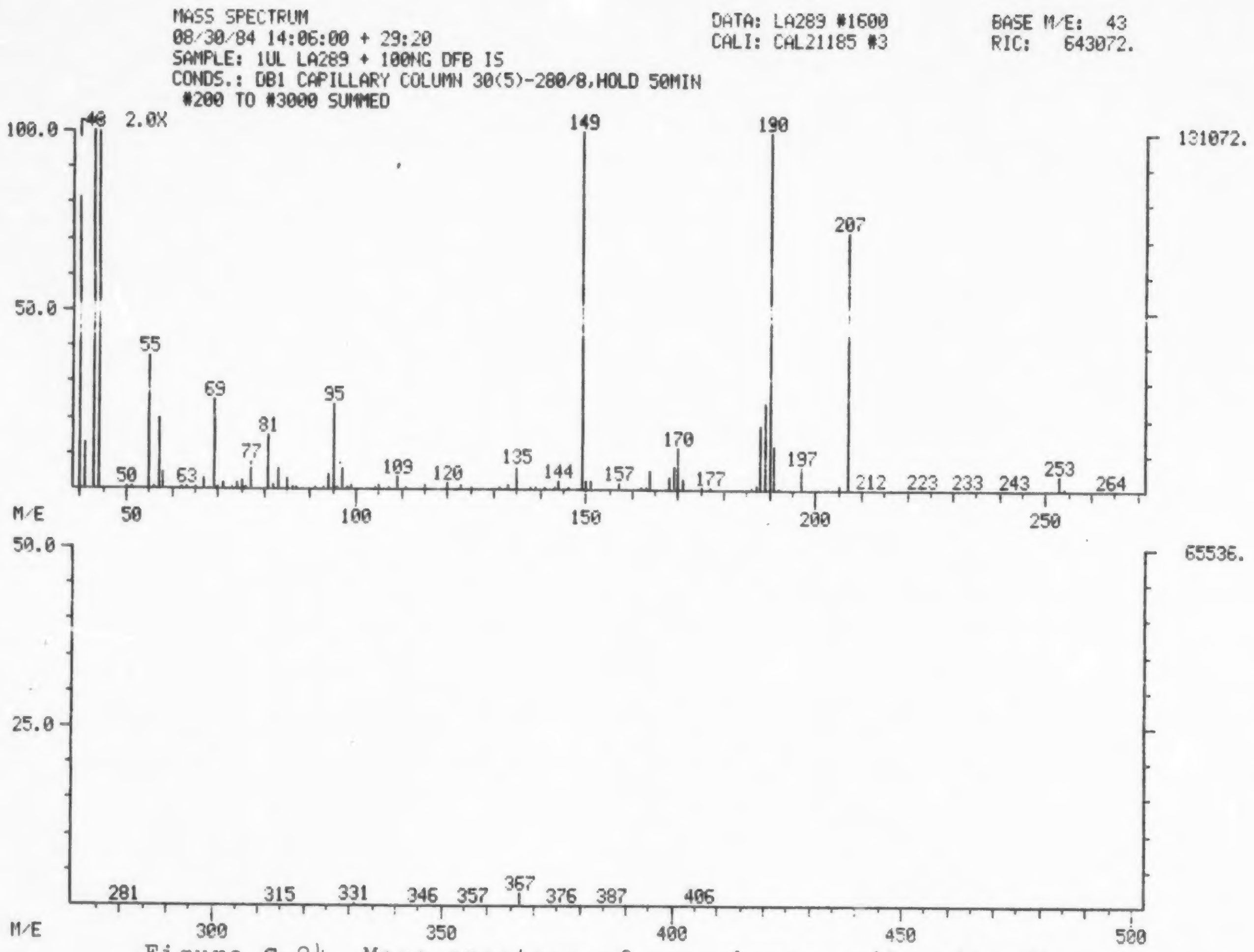
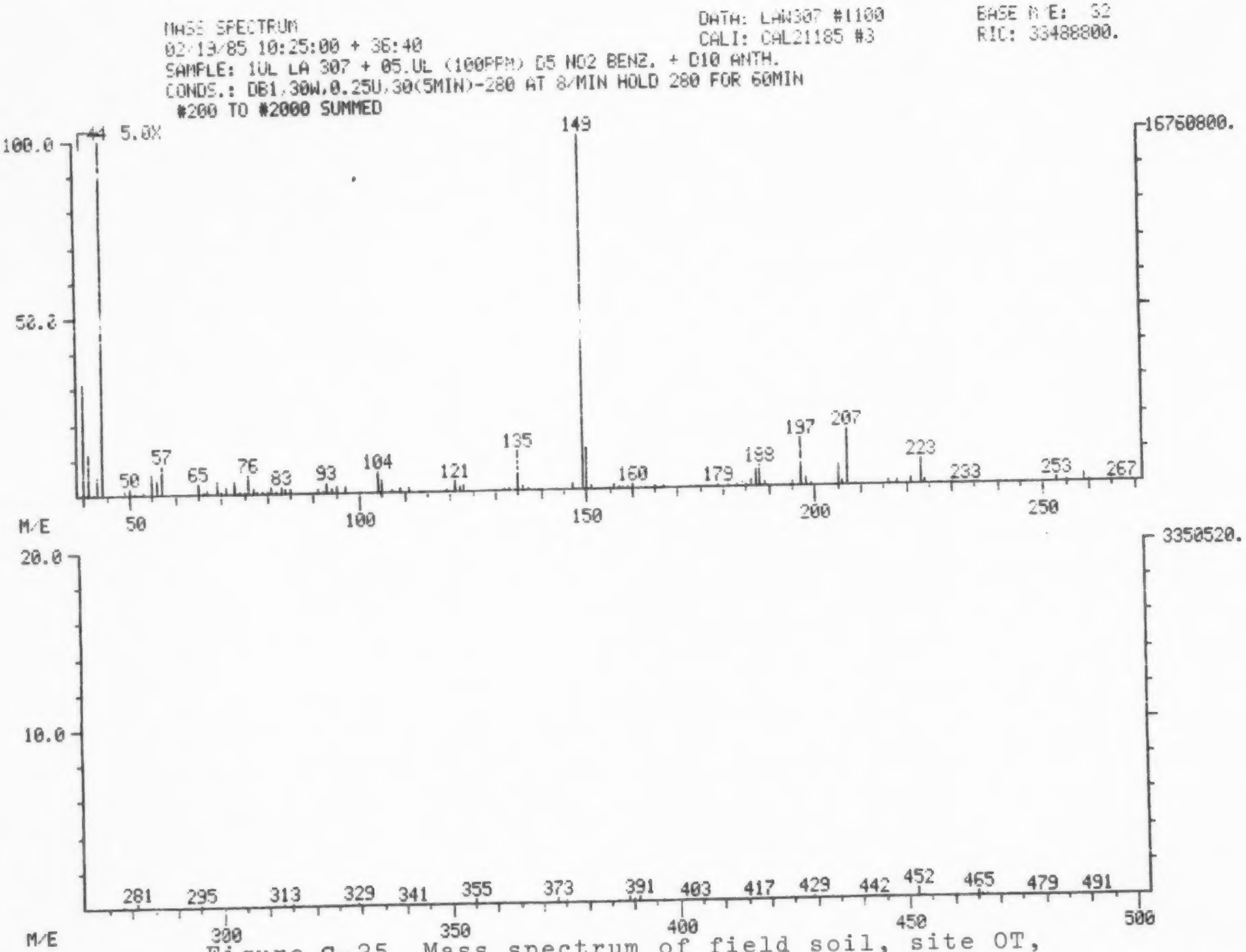
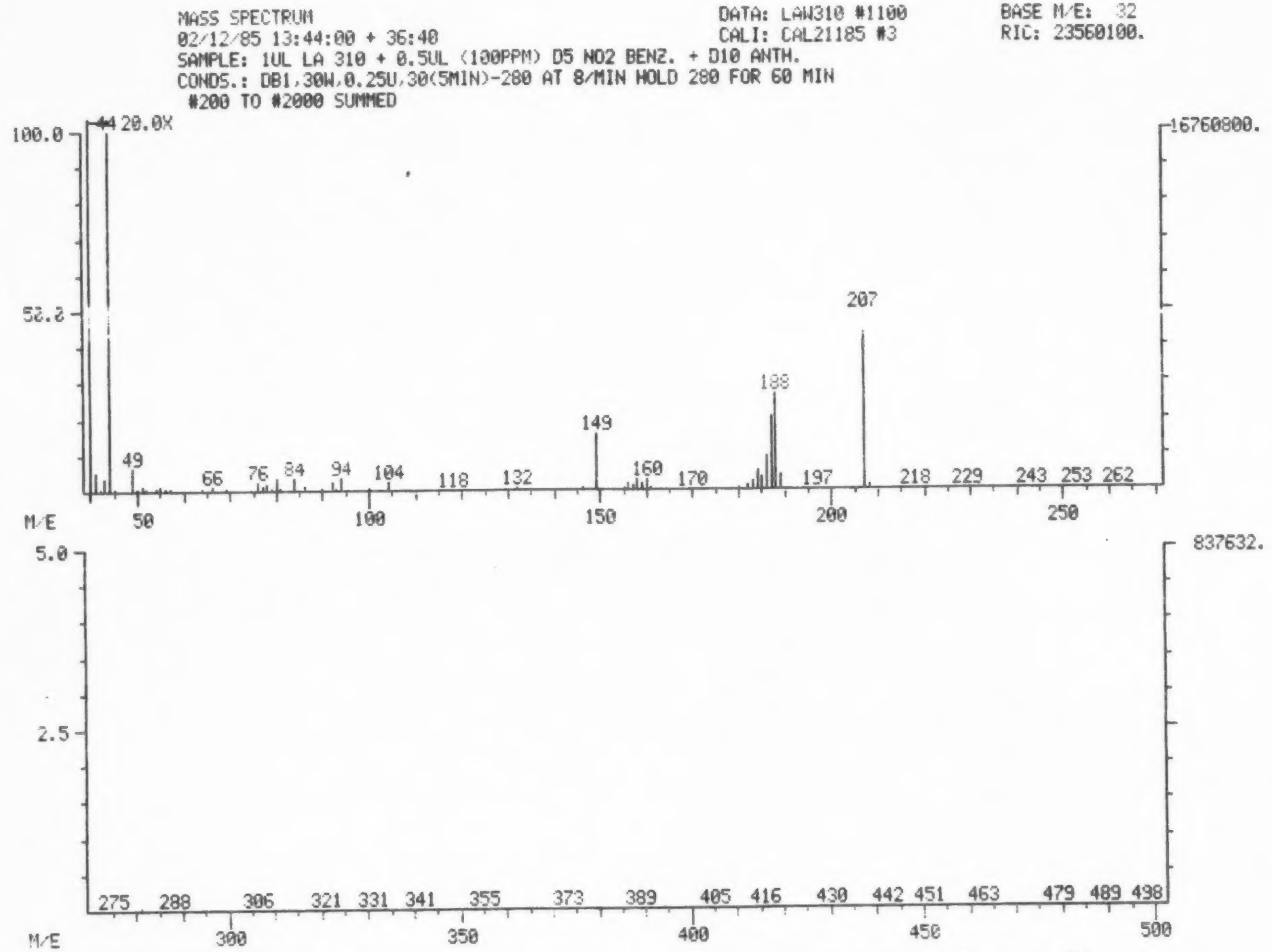


Figure C-24 Mass spectrum of greenhouse soil, site WA, June 1984, control pots, surface sample.



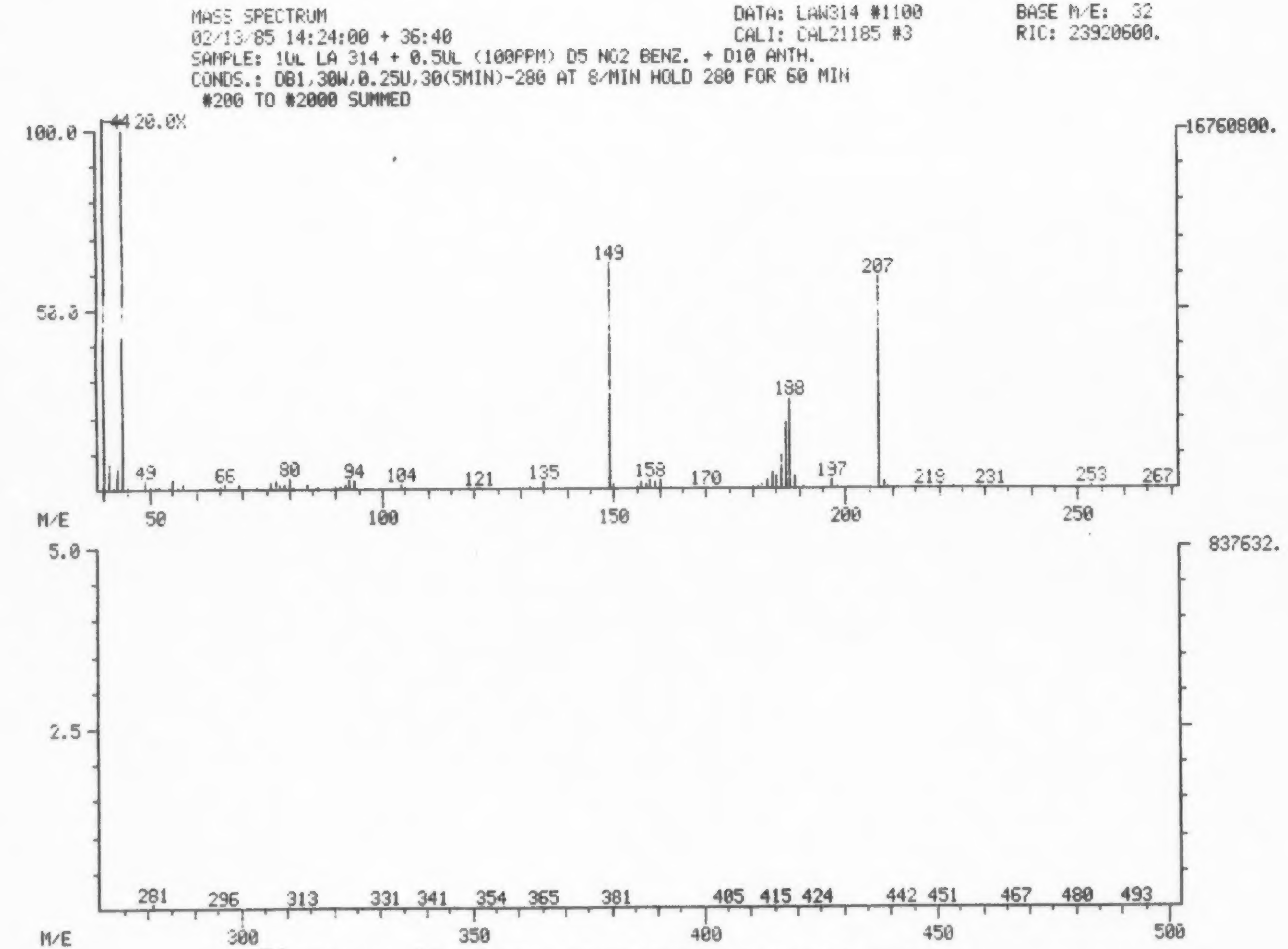
```
MASS SPECTRUM                                          DATA: LAN307 #1100        BASE M/E: 32
02/13/85 10:25:00 + 36:40                              CALI: CAL21185 #3         RIC: 33488800.
SAMPLE: 1UL LA 307 + 05.UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN HOLD 280 FOR 60MIN
 #200 TO #2000 SUMMED
```

Figure C-25 Mass spectrum of field soil, site OT, November 1984, control plot, surface sample.



```
MASS SPECTRUM                                      DATA: LAW310 #1100        BASE M/E:  32
02/12/85 13:44:00 + 36:40                          CALI: CAL21185 #3         RIC: 23560100.
SAMPLE: 1UL LA 310 + 0.5UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN HOLD 280 FOR 60 MIN
 #200 TO #2000 SUMMED
```

Figure C-26 Mass spectrum of field runoff, November 1984, unvegetated plot, filtered sample.



```
MASS SPECTRUM                                          DATA: LAW314 #1100        BASE M/E:  32
02/13/85 14:24:00 + 36:40                              CALI: CAL21185 #3         RIC: 23920600.
SAMPLE: 1UL LA 314 + 0.5UL (100PPM) D5 NO2 BENZ. + D10 ANTH.
CONDS.: DB1,30W,0.25U,30(5MIN)-280 AT 8/MIN HOLD 280 FOR 60 MIN
 #200 TO #2000 SUMMED
```

Figure C-27 Mass spectrum of field runoff, November 1984, control plot, filtered sample.

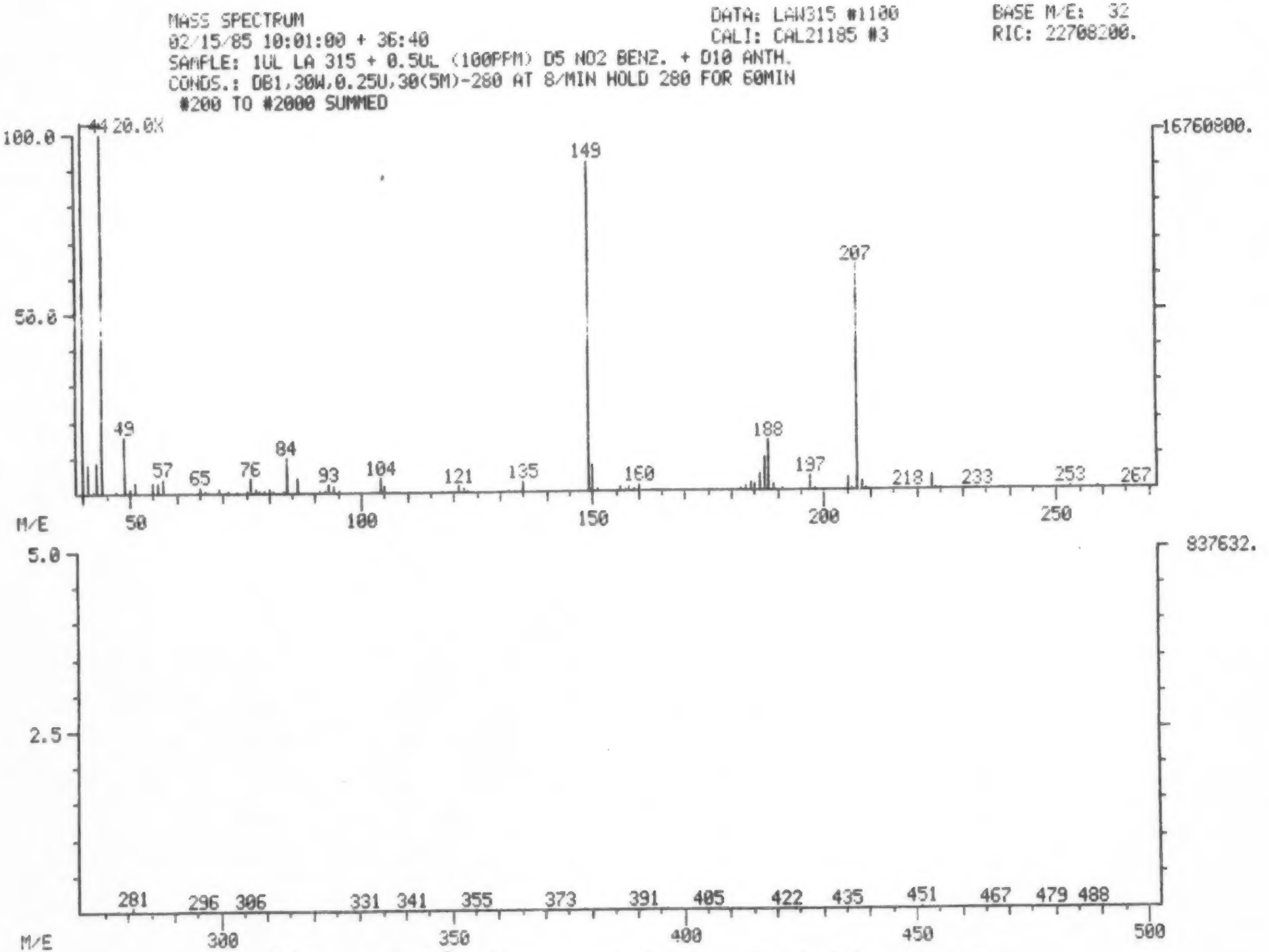


Figure C-28 Mass spectrum of field runoff, November 1984, control plot, unfiltered sample.

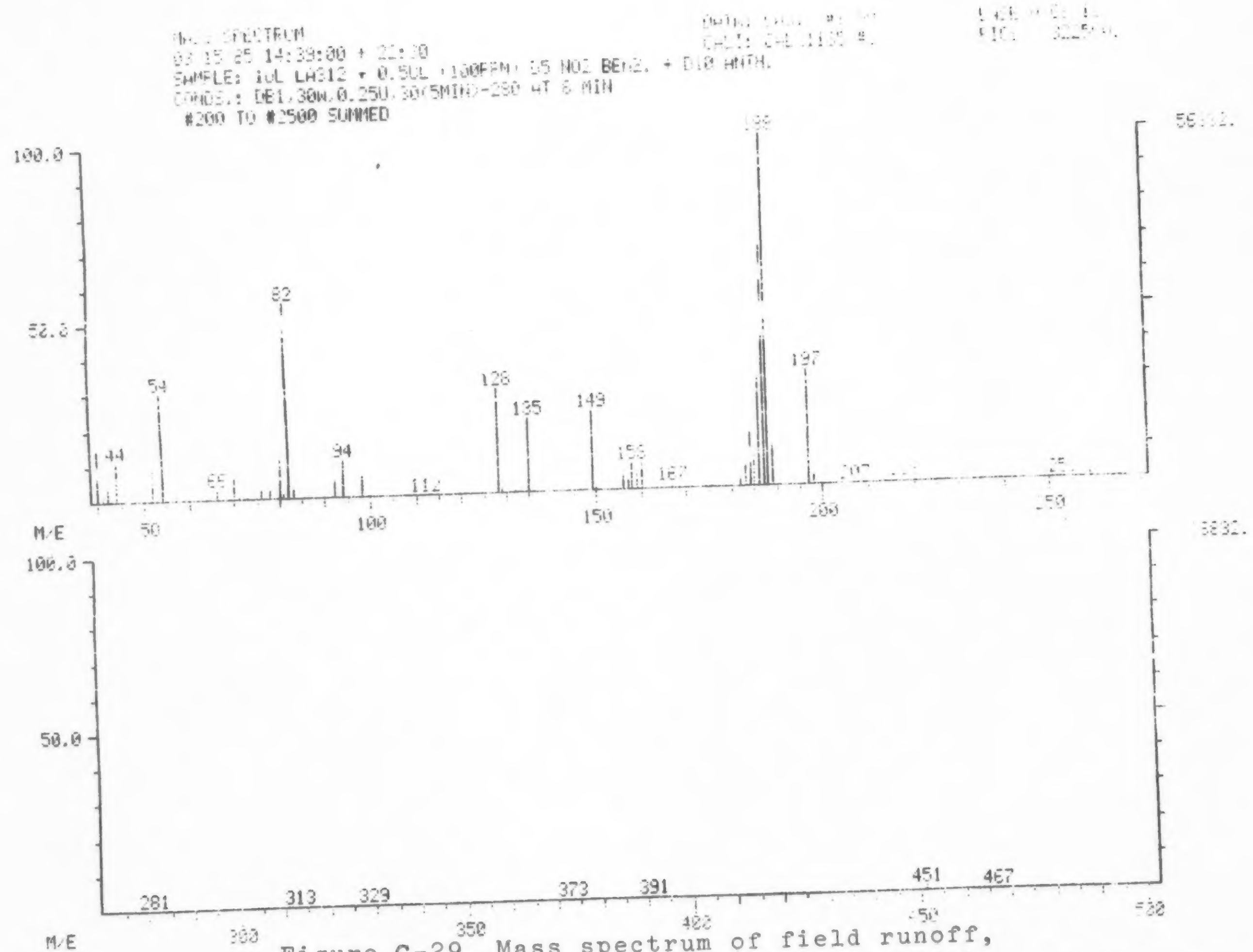


Figure C-29 Mass spectrum of field runoff, November 1984, vegetated plot, filtered sample.

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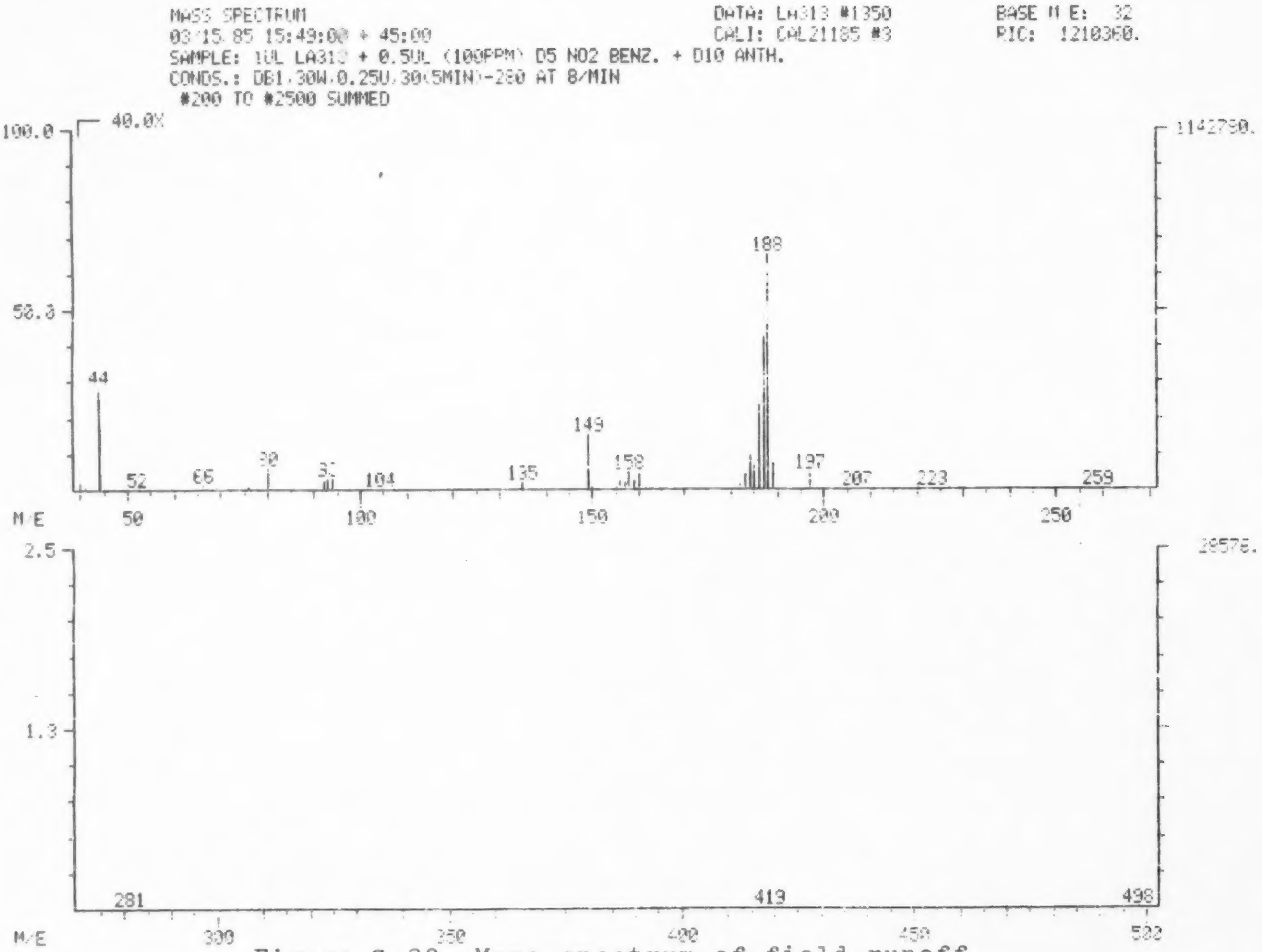

Figure C-30 Mass spectrum of field runoff, November 1984, vegetated plot, unfiltered sample.

Reproduced from best available copy.

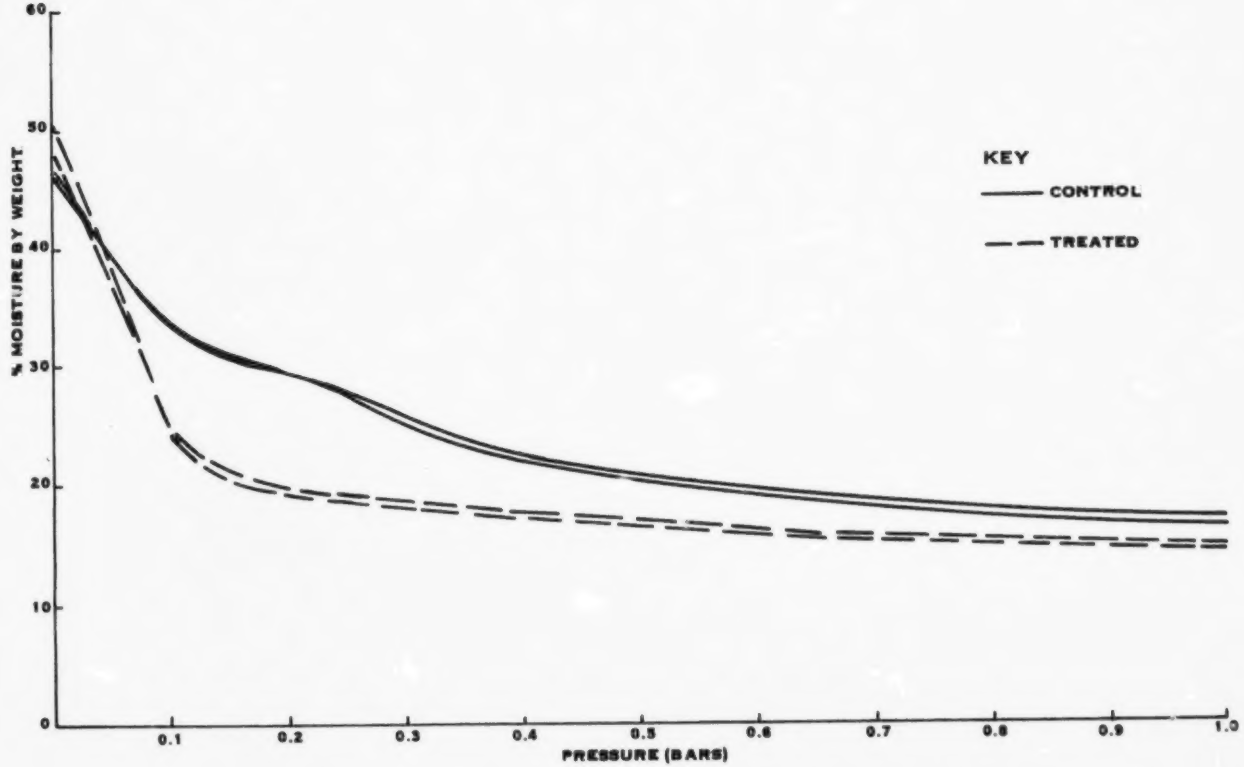

FIGURE D-1 SOIL MOISTURE CHARACTERISTIC CURVES FOR SITE OP SOILS

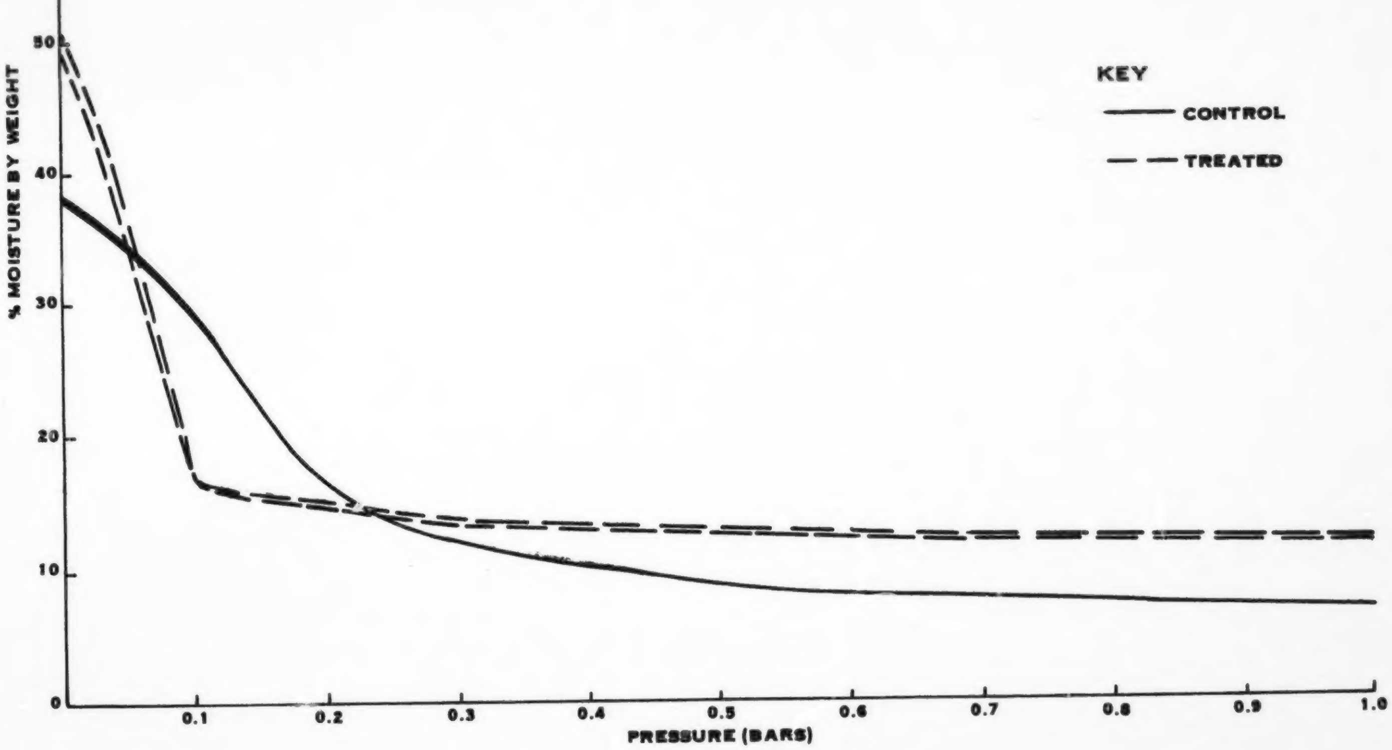

FIGURE D-2 SOIL MOISTURE CHARACTERISTIC CURVES FOR SITE OT SOILS

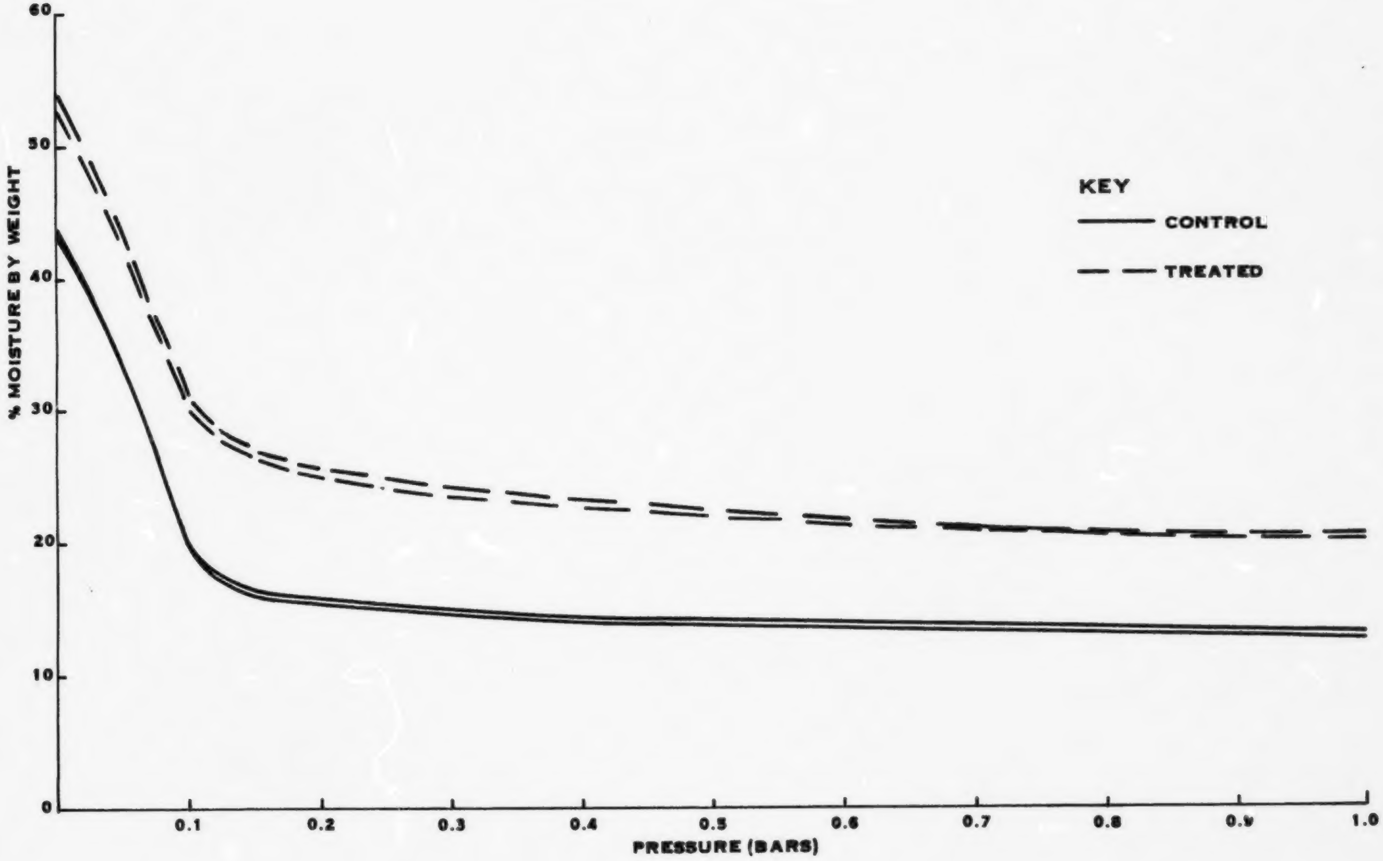

FIGURE D-3 SOIL MOISTURE CHARACTERISTIC CURVES FOR SITE TX SOILS

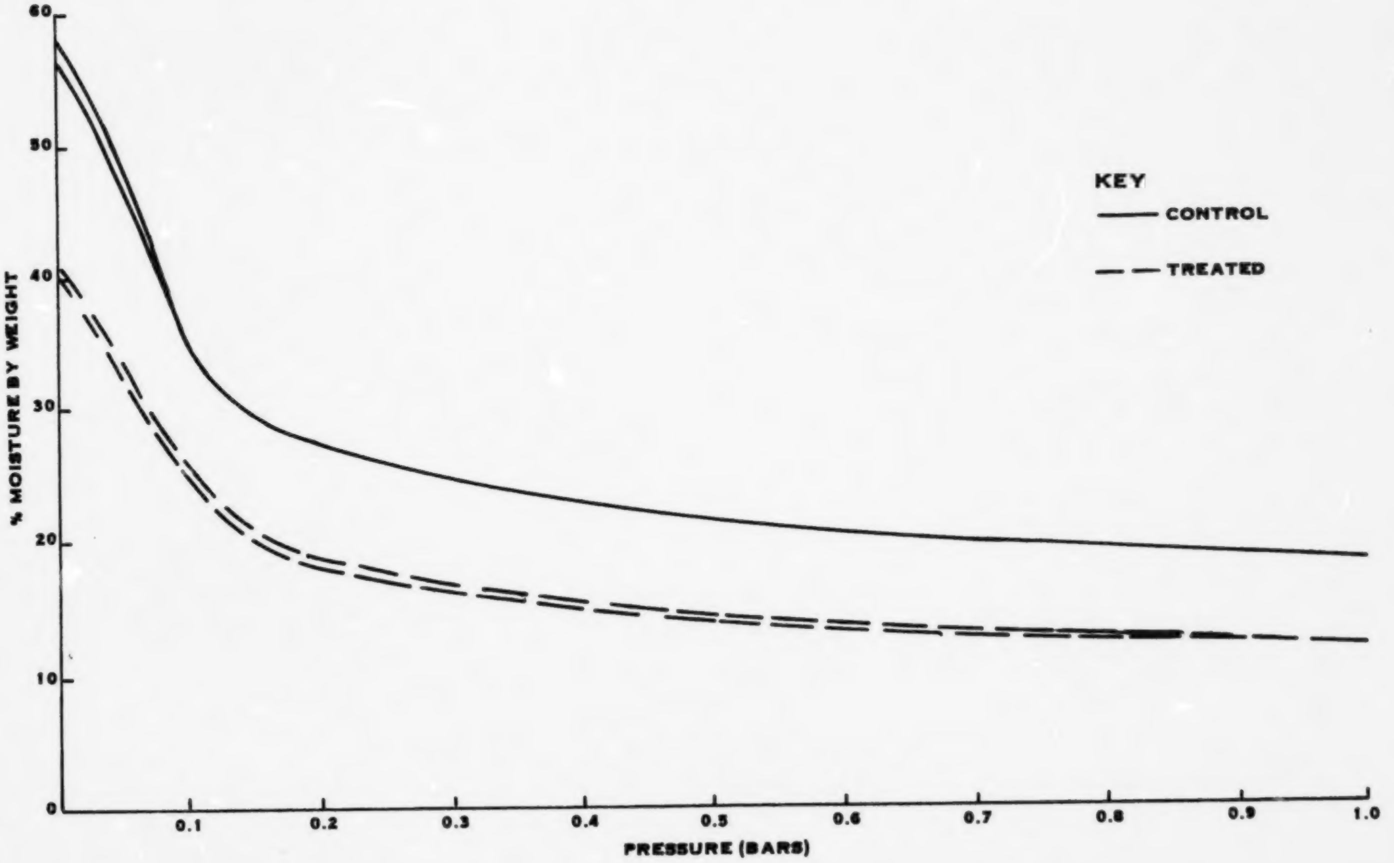

FIGURE D-4 SOIL MOISTURE CHARACTERISTIC CURVES FOR SITE WA SOILS